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Distribution, habitat preferences and population sizes of two threatened tree ferns, *Cyathea cunninghamii* and *Cyathea* x *marcescens*, in south-eastern Australia.

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Abstract: The distribution, population sizes and habitat preferences of the rare tree ferns *Cyathea cunninghamii* Hook.f. (Slender Tree Fern) and F1 hybrid *Cyathea* x *marcescens* N.A.Wakef. (Skirted Tree Fern) in south-eastern Australia are described, together with the extension of the known distribution range of *Cyathea cunninghamii* from eastern Victoria into south-eastern New South Wales. Floristic and ecological data, encompassing most of the known habitat types, vegetation associations and population sizes, were collected across 120 locations. Additional information was sought from literature reviews, herbarium collections and field surveys of extant populations.

Cyathea cunninghamii is widespread, with the majority of populations occurring in Tasmania and Victoria, one population in south-eastern NSW and a disjunct population in south-eastern Queensland; *Cyathea* x *marcescens* is confined to south and eastern Victoria and south and north eastern Tasmania. Both taxa occur on King Island in Bass Strait. Both taxa have a near coastal distribution with most populations occurring in sub-coastal hinterland and escarpment forests with a median altitude of 288 m. Hierarchical cluster analysis of floristic data across the species' geographic range identified six vegetation communities ranging from rainforest to damp sclerophyll forest. Their micro-habitat preferences were consistently identified as steeply incised gullies of minor headwater streams of coastal and sub-coastal ranges with a plentiful moisture regime and geomorphic protection from extreme stream flow events, flooding and bank scouring. Sporophyte recruitment was associated with exposed soil of stream banks and edges of constructed walking tracks.

Population sizes of both taxa are small with the majority of populations consisting of less than five adult individuals, with total populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* estimated at 919 and 221 mature individuals respectively.

Population extinctions in Victoria and Tasmania have primarily been associated with outlier populations in regions subject to agricultural land clearance, habitat modification and changes to fire regimes in crown forests. Non-anthropogenic mortality was associated with land slips, tree falls and stream bank scouring by flood water. Conservation of the hybrid *Cyathea* x *marcescens* necessitates the preservation of habitats where both *Cyathea cunninghamii* and *Cyathea australis* occur in close proximity to substrates suitable for spore germination. In future, molecular techniques may prove useful for field identification of juvenile stages, facilitating selection of progeny of *Cyathea cunninghamii* and *Cyathea* x *marcescens* for cultivation and re-introduction to sites of previous or possible future extinctions.

Key Words: Tree fern, *Cyathea australis, Cyathea cunninghamii, Cyathea* x *marcescens,* threatened species, Australia, hybrids, Cyatheaceae

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Introduction

Tree ferns are of considerable ecological and aesthetic significance in moist forest communities of south eastern Australia. Due to their appeal to professional botanists, naturalists and the general public, tree ferns have been extensively studied and reported for their ecophysiological tolerances (Hunt et al. 2002, Volkova et al. 2009, 2010a,b,c), their horticultural and amenity use (Anon 1873, Attenborough 1997, Braggins & Large 2004, Jones & Clemesha 1976, Robbin 1985, Garrett 1998, Unwin & Hunt 1996, Wardlaw 1997) and their role as keystone species in forest regeneration dynamics (Gaxiola et al. 2008, Ough & Murphy 2004, Smale et al. 1997). The important role tree ferns play in the ecology of forest systems has been recognised in some of the earliest Australian and New Zealand forest ecological studies (Patton 1933, Petrie et al. 1929, Pope 1924, 1926). More recently they have been the subject of increased scientific study as a result of export harvest regulations (Department of Natural Resources & Environment 2002, Forest Practices Board 2005), on-ground management (Forest Practices Board 2003), their potential for production and sale from plantation estates (Unwin & Hunt 1997), regional conservation assessments (Garrett 1997) and their role as host substrates for vascular and non-vascular epiphytes across multiple continents (e.g. Beever 1984, Ford & Gibson 2000, Floyed & Gibson 2006, Gillman & Ogden 2005, Mehltreter et al. 2005, Page & Brownsey 1986, Peacock & Duncan 1994, Roberts 2002, Roberts et al. 2003, 2005). Of the tree fern species present in New South Wales (*Dicksonia antarctica*, *Dicksonia youngiae*, *Cyathea australis*, *Cyathea cooperi*, *Cyathea cunninghamii*, *Cyathea leichhardtiana*, *Todea barbara*), Victoria (*Dicksonia antarctica*, *Cyathea australis*, *Cyathea cunninghamii*, *Cyathea leichhardtiana*, *Cyathea* x *marcescens*, *Todea barbara*) and Tasmania (*Dicksonia antarctica*, *Cyathea australis*, *Cyathea cunninghamii, Cyathea* x *marcescens*, *Todea barbara*) the only taxa of conservation significance across their range are *Cyathea cunninghamii* and *Cyathea* x *marcescens*. *Cyathea leichhardtiana* is considered vulnerable (Flora and Fauna Guarantee Act 1988 Section 10) and threatened (Department of Sustainability and Environment 2005) in Victoria due to its limited distribution to the far eastern corner of that State.

The Slender Tree Fern, *Cyathea cunninghamii* (Cyatheaceae) (Figure 1), has a tall, narrow, erect trunk (caudex) to 20 metres high, from 7 to 20 cm in diameter (up to 28 cm in New Zealand), with a small crown of fronds (Duncan & Neyland 1986, Entwisle 1994). Reproductive structures are the most reliable diagnostic features and the indusia are well formed, prominent, more or less enclosing the sori when young, but opening to form a hood-like structure with a notch at the margin at maturity (Duncan & Neyland 1986, Bostock pers. comm. 2007).

In Australia *Cyathea cunninghamii* is known from Tasmania, Victoria, New South Wales and Queensland. The Tasmanian populations are almost exclusively near-coastal and are distributed discontinuously from the Southern Forests, the Tasman Peninsula, the east and west coast, the north west and King Island (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania 2011a). In Victoria *Cyathea cunninghamii* is recorded from the Otway Ranges, Yarra Ranges, South Gippsland and Wilsons Promontory, and from East Gippsland. For decades, the status of *Cyathea cunninghamii* in NSW has been unclear and its occurrence was either questioned (Jones & Clemesha 1976) or dismissed (Wakefield 1975). A specimen collected by the principal author in 1989 from a single plant growing in Maxwells Flora Reserve in Nadgee State Forest could not be precisely identified as the sori were over-mature and the key soral characters mostly lacking (Bostock 1998). In 1999 a subsequent collection from the same plant (NSW 449793–449796) was reproductively mature and determined as *Cyathea cunninghamii.* A specimen (BRI AQ331459) cited as *Cyathea cunninghamii* from Dorrigo northern NSW and referred to by Bostock (1998), was subsequently re-determined as *Cyathea australis* (Bostock pers. comm. 2007). There is a disjunct population in Lamington National Park in south-eastern Queensland from complex notophyll vine forest (Sattler & Williams 1999). This location is significant as it is the northern climatic limit of several cool subtropical species including the relictual species *Nothofagus moorei, Ochrosia moorei* and *Pandorea baileyana* (Sattler & Williams 1999, Queensland Department of Environment and Heritage 1998). The distribution in Lamington National Park has two known 'centres': Toolona Creek (the western branch of Canungra Creek) and Gwahlahla Falls at the headwaters of the Albert River. *Cyathea cunninghamii* is also known from New Zealand where it is not considered threatened (Brownsey 1979, Brownsey et al. 1985, Brownsey & Smith-Dodsworth 2000, de Lange et al. 2009). Nationally, *Cyathea cunninghamii* is listed as rare in the ANZECC Threatened Australian Flora list (1999) but is not listed in the Environment Protection and Biodiversity Conservation Act 1999. In Tasmania it has been listed as rare by the Flora Advisory Committee (1994) and endangered in the Threatened Species Protection Act 1995. In Victoria it is listed as threatened in the Victorian Flora and Fauna Guarantee Act 1988 Section 10 (2012). In Queensland, *Cyathea cunninghamii* is listed as near threatened in the Queensland Nature Conservation Act 1992. Currently there are no *Cyathea* species listed as threatened species under the NSW Threatened Species Conservation Act 1995.

The Skirted Tree Fern *Cyathea* x *marcescens* (Cyatheaceae) (Figure 2) (Wakefield 1942) is considered to be a sterile F1 hybrid between *Cyathea australis* and *Cyathea cunninghamii* (Wakefield 1975, Hill 1984, Duncan & Isaac 1994) with a range of morphological characteristics and ecological preferences evident in the offspring. The spores produced by *Cyathea* x *marcescens* are typical of those described for sterile fern hybrids (Wagner & Wagner 1986), being defective by nature of the collapse of the exospore and the absence of protoplast (Thiele pers. comm. 2011). *Cyathea* x *marcescens* differs from *Cyathea cunninghamii* in having a much thicker (up to 30 cm diameter) and shorter (to 10 metres) caudex, a very large, thick crown of fronds, rough, crumbly, black stipe bases and, usually, a persistent skirt of

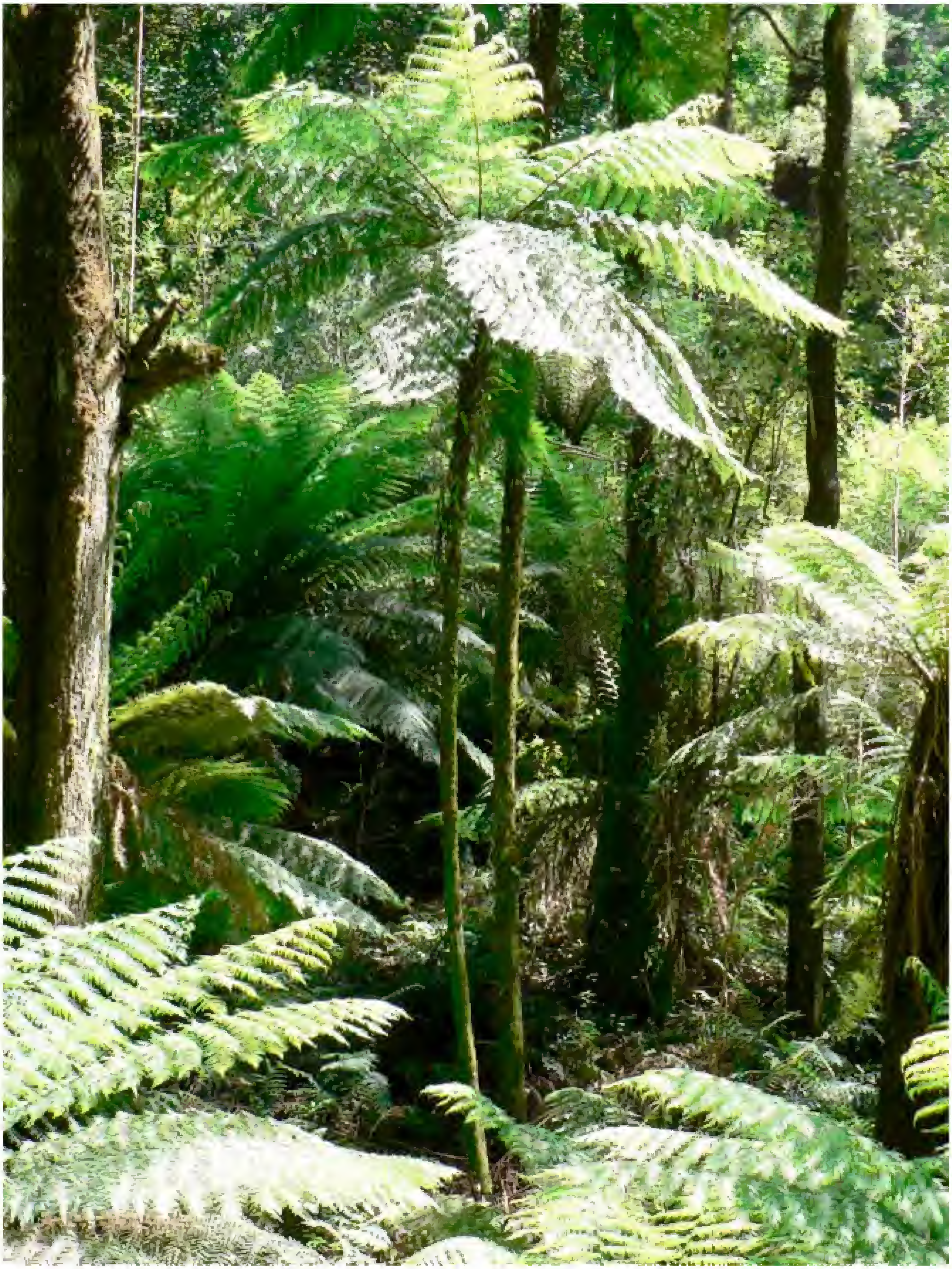

Fig. 1. Two individuals of *Cyathea cunninghamii* at Dandenong Ranges National Park (Vic.) in plant community 1 (Wet sclerophyll Forests and Fern gullies, see Appendix1). The species often appears as a solitary adult plant or in small groups of 1-3 individuals in the deepest most sheltered portions of fern gullies. *Dicksonia antarctica* is the conspicuous understorey fern species. Photograph Ross Peacock

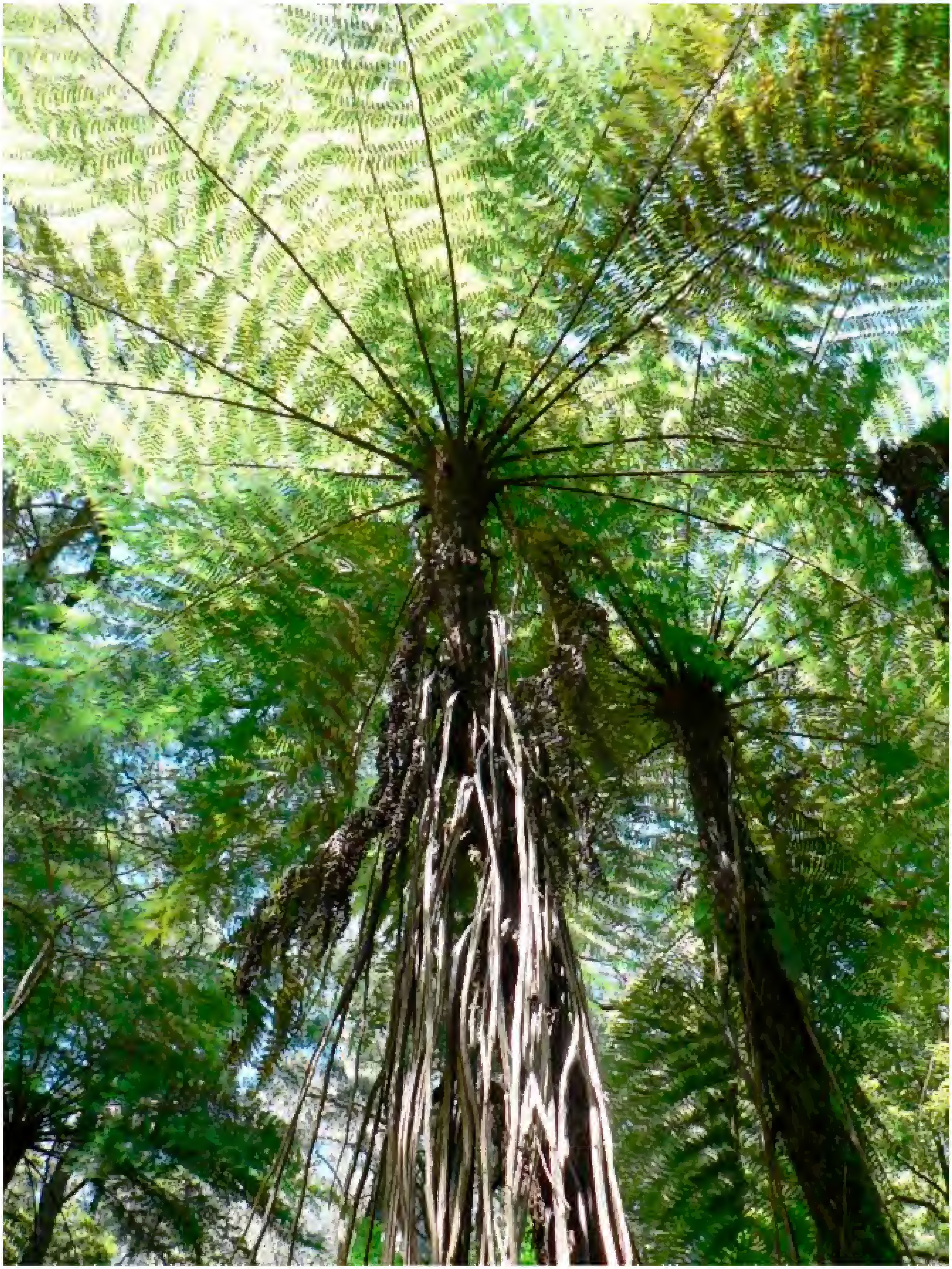

Fig. 2. Skirted Tree Fern, *Cyathea marcescens*, Dandenong Ranges National Park (Vic.) in plant community 1 (Wet sclerophyll Forests and Fern gullies, see Appendix1). Note the characteristic skirt of dried frond stipes attached to the caudex. Photograph Ross Peacock

dead fronds (see Figure 2). There are also differences in the reproductive structures. Sori of *Cyathea* x *marcescens* are produced in roughly semi-circular, low, cup-like indusia with irregular margins (Duncan & Isaac 1994, Bostock pers. comm. 2007).

Cyathea x *marcescens* is distributed across East Gippsland, Victoria, at Mount Drummer (lectotype location MEL 1513089 2 February 1941), Combienbar, Errinundra NP, Howe Ranges near the NSW border, Dandenong Ranges National Park east of Melbourne, Tarra-Bulga NP in South Gippsland and numerous reserves in the Otway Ranges (Walsh & Entwisle 1994). In Tasmania, it has been recorded at Marsh Creek and Little Beach Creek near Elephant Pass in the north-east of the state, at Fortescue Bay in the south and at Grassy River on King Island (Garrett 1997, Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011b). While *Cyathea* x *marcescens* was not described until 1942 (Wakefield 1942), specimens of uncertain status were collected from 1880 in Victoria and Tasmania, identified initially as *Cyathea medullaris* and later re-determined as *Cyathea* x *marcescens*. Nationally *Cyathea* x *marcescens* is not listed by the Environment Protection and Biodiversity Conservation Act 1999**.** However, it is listed as endangered in Tasmania under the Tasmanian Threatened Species Protection Act 1995 but has not been listed by the Tasmanian Flora Advisory Committee (1994). In Victoria it is listed as vulnerable in the Advisory List of Rare or Threatened Plants (2005) but is not listed in the Flora and Fauna Guarantee Act Threatened Species List (2012).

Precise identification of young plants has been difficult as *Cyathea cunninghamii* can take 20–30 years to reach sexual maturity and accurate identification has been based on characteristics of the sori. This task is made more difficult by the range of variation seen in provenances of *Cyathea* x *marcescens*, intermediate between the two parent species (Keel 1993).

This study was undertaken to determine the distribution, population sizes and habitat preferences of the rare tree ferns *Cyathea cunninghamii* and *Cyathea* x *marcescens* in south eastern Australia and also to report on the extension of the known distribution range of *Cyathea cunninghamii* into New South Wales.

Methods

Distribution

Distributional data for *Cyathea cunninghamii* and *Cyathea* x *marcescens* were compiled from literature sources, herbarium collections, databases held by government agencies and from interviews with field naturalists. Publically available national databases, such as the Australian Virtual Herbarium (AVH: www.chah.gov.au/avh) and Atlas of Living Australia (ALA: www.ala.org.au) were examined; however the policy of denaturing location, habitat and population information for rare plant species limits their utility where data matching from multiple sources is required to compile an accurate database (see Kooyman et al. 2012). For Victoria, the Royal Botanic Gardens Melbourne MELISR database was used to extract herbarium data, and the Department of Sustainability and Environment VROT population database was used to extract records from incidental sources and definable areas. Quadrat data, which included either or both taxa, was extracted from the Victorian Department of Sustainability and Environment Flora Information System. For New South Wales, Queensland and Tasmania herbarium data was also extracted from the specimen databases, and the specimen collections directly examined. The compiled distributional data was validated with duplicate or redundant records removed. The compiled distribution data were used to develop a strategy to plan population field surveys which addressed pertinent gaps in current knowledge of the species distribution of each taxa, population sizes, habitat preferences and threatening processes, using approaches advocated by Keith (2000).

Population sizes

Adult population sizes were estimated from published and unpublished literature, herbarium collections, floristic databases and from field searches of known or reported populations. Unlike most vascular plant species, where population sizes are usually estimated using a sampling and prediction approach, populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* in most cases were so small, discrete and limited in spatial extent that the adult plants could be subject to a direct census. Confidence in the population size estimates was therefore generally high except for the largest populations (50–200 adult individuals) where a sampling process was adopted.

Habitat descriptions from the literature and herbarium data were used to focus field searches to areas where there was a higher probability of detection. Plot-less traverses were conducted within suitable habitats in the vicinity of known or reported populations to refine population estimates and determine population extent. Where multiple population estimates for the same locality were available in the literature the most recent was used.

In order to minimise the risk of incorrect identification, only individuals with a caudex were used to estimate the size of extant populations. Estimates of the number of young sporophytes present were made during field searches but were not included in the estimate of population sizes due to the difficulty of accurate identification. When herbarium records were used to determine population sizes, a population was considered distinct if the record held sufficiently precise information to determine that the population could be recognised as geographically distinct from other collections in the immediate vicinity.

An expert approach was adopted to estimate the pre-European populations of both taxa for each region. The extant distribution was compared to the known extent of both taxa from herbarium data and naturalists' publications from the late nineteenth century, and intersected with the extent and degree of habitat modification, land clearance, wildfire, timber harvesting, poaching and non-anthropogenic events in those regions from the time of European settlement. For each region and taxon a simple formula was followed where the existing population size of each taxon was given a confidence interval based on the assumed adequacy of the existing survey effort in suitable habitat multiplied by a population ‘expansion’ factor derived from the above parameters (eg proportion of suitable habitat land cleared versus undisturbed etc). .

Table 1. Adult population characteristics for *Cyathea cunninghamii* and *Cyathea marcescens* throughout their range in Victoria, Tasmania, NSW and Queensland (includes all reliable records from those states).

	Cyathea cunninghamii	*Cyathea* x *marcescens*
Mean population size	7.7	5.9
Median population size	3	4
Total number of individuals	919	221

Habitat Preferences

Floristic data on extant populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* were compiled from public databases to describe habitat preferences, floristic affinities and broad scale distribution. An initial quantitative examination of the floristic data was undertaken to identify gaps in spatial coverage and un-sampled vegetation communities where both taxa were known from the literature or herbarium records. Additional floristic sampling was then undertaken in the Dandenong Ranges, South, Central and East Gippsland in Victoria and in southern New South Wales.

Floristic data were collected using 30 x 30m quadrats within a uniform stand of vegetation. Where plant communities were less than 30 m wide, for example along creeks, the quadrat shape was altered and a rectangle that enclosed the same area was sampled. All vascular plant species in each quadrat were assigned a visually assessed combined cover abundance value. Cover was measured in the field as projective foliage cover using the Walker & Tunstall (1981) definition. Structural information was collected on the height, cover and dominant species of each recognisable vegetation stratum in addition to a general habitat description of elevation, aspect, geology, soils, ground cover and disturbance history. Nomenclature follows Walsh & Stajsic (2007) for Victoria and Baker & de Salas (2012) for Tasmania.

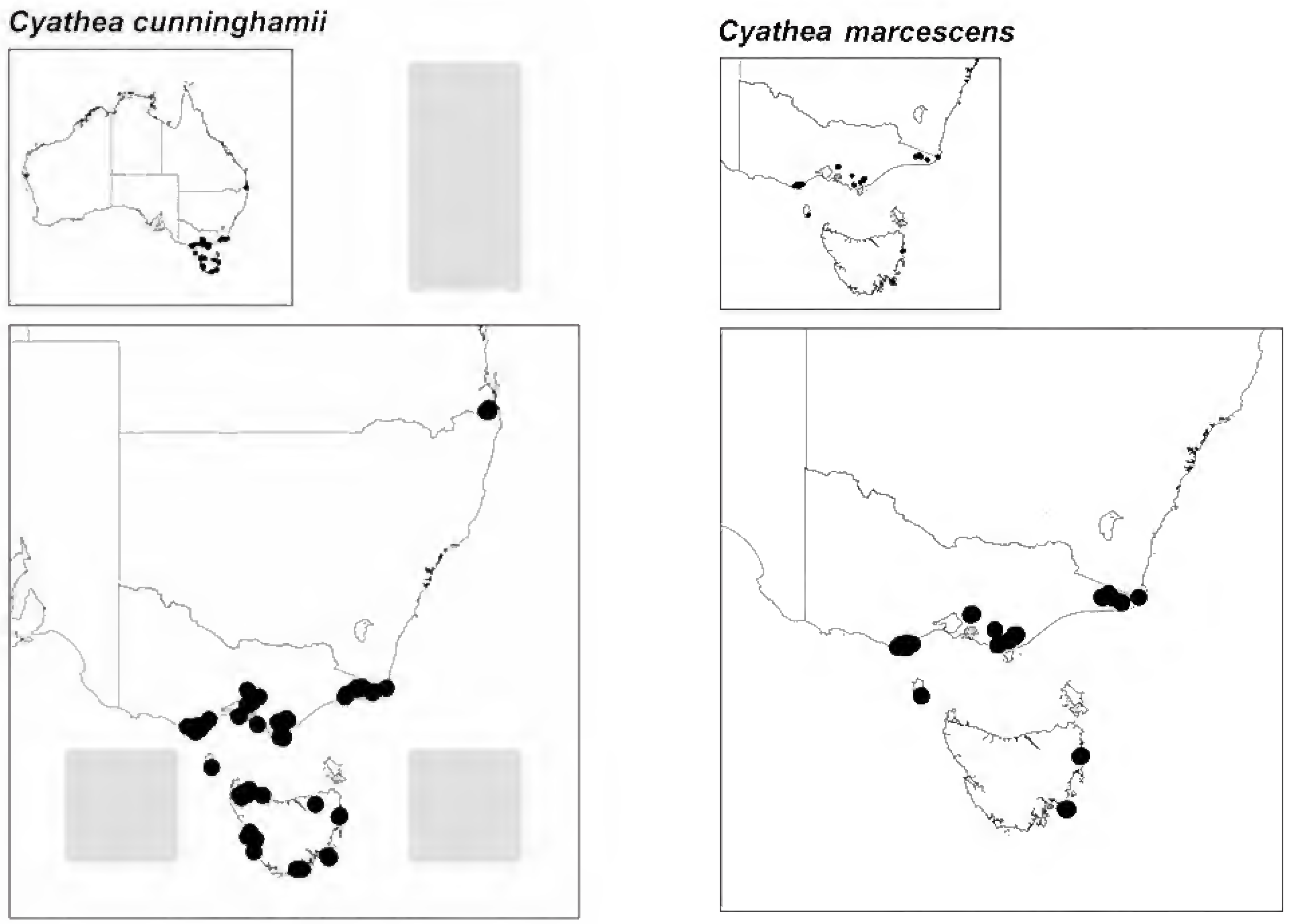

Fig. 3. Distribution of *Cyathea cunninghamii* (3a, 3b) and *Cyathea marcescens* (3c, 3d) in Australia (Atlas of Living Australia 2012a,b). Owing to the sensitive nature of precise locations for rare and/or endangered species, these maps are intended only as a guide to the distribution of each taxon.

Table 2a. Number of adult populations and their size estimates for *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout Victoria, Tasmania, New South Wales and Queensland (includes all reliable records from those states).

	Cyathea cunninghamii			*Cyathea* x *marcescens*		
	Number of populations	Total number of adult plants	Median number of individuals per population	Number of populations	Total number of adult plants	Median number of individuals per population
Tasmania	18	238	8	4	38	6
Dandenong Ranges, Victoria	1	19	19	2	23	9
East Gippsland, Victoria	25	115	3	10	53	4
Otway Ranges, Victoria	38	127	3	11	23	1
Central Highlands, Victoria	1	1	1	-	-	-
South and Central Gippsland, Victoria	32	403	3	9	84	-
New South Wales	1	1	1	-	-	-
Queensland	1	15	15	-	-	-
Total	117	919		36	221	

Table 2b. Estimated pre-European adult populations sizes for *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout Victoria, Tasmania, New South Wales and Queensland taking historical events and impacts into account.

Region	***Cyathea cunninghamii***	***Cyathea marcescens***	**Historical impacts**
Tasmania	700	120	Land clearance, agricultural development, severe wildfire events in 1897, 1934 & 1967
Yarra Ranges, Victoria	120	80	Land clearance, wildfires in 1851 and 1939, poaching, weed infestation, windthrow, encroachment
East Gippsland, Victoria	500	150	Habitat modification associated with extensive forest grazing and burning in the 1800s and timber harvesting in 1900s, wildfires in 1939 and 1983 and overall decline in lowland rainforest habitat, alluvial creek mining and prospecting and associated burning in 1800s
Otway Ranges, Victoria	500	60	Wildfires in 1919, 1939, decline in rainforest and fern gully habitat associated with timber harvesting, fire and potentially *Nothofagus* canopy dieback, land clearance for agriculture
Central Highlands, Victoria	100	10	Wildfires in 1926, 1939 and 2009, decline in rainforest and fern gully habitat associated with timber harvesting, alluvial creek mining and associated burning in 1800s
South and Central Gippsland, Victoria	1500	300	Land clearance and habitat modification in west and south Gippsland due to agricultural development, land clearance in central and south Gippsland due to plantation development and wildfires in 1898, 1914, 1932, 1939 and 1965
New South Wales	30	10	Integrated forest harvesting, impacts of wildfires in 1939, 1952 and 1980 on remnant rainforest in far south eastern NSW, rainforest canopy dieback since 1980s and associated tree windthrow into creeks
Queensland	40	-	Habitat along creeks associated with waterfalls is considered relatively stable
Total	3500	730	

The visually assessed cover abundance values derived from each 30 x 30 m quadrat were converted to the mid-point of the respective cover class. An association matrix of the 120 quadrats and 191 species was compiled using the Bray-Curtis distance measure (Bray & Curtis 1957). As a preliminary step in reducing noise in the data set a frequency distribution of average Bray-Curtis distance measures was constructed and statistical outliers identified as those quadrats with a mean distance measure of greater than three standard deviations from the grand mean distance measure of all pair-wise comparisons. This step removed the single quadrat from Lightning Falls at Lamington National Park Queensland which alone introduced 21 unique warm temperate and sub-tropical taxa to the analysis. The data set used in the analysis was reduced to 119 quadrats and 170 species.

The multivariate relationships between floristic composition and environmental correlates were examined using ordination and classification. The ordination technique was non-metric multidimensional scaling (NMS). NMS ordinations in the global form were derived from 50 multiple runs, using 10 different random starting configurations, with a maximum of 100 iterations. Ordinations were performed in 1–3 dimensions, and the minimum stress solutions for each dimension examined. Stress is 'a measure of departure from monotonicity in the relationship between the dissimilarity (distance) in the original p-dimensional space and distance in the reduced k-dimensional ordination space' (McCune & Mefford 1999). The two dimensional solution was chosen as the appropriate number of dimensions (axes) following an examination of the final stress versus the number of dimensions. The stability criterion for terminating successive iterations was 0.001. The axis scores from the two dimensional solution were saved and examined graphically using two dimensional plots rotated on the x-axis and through graphical overlays. Hierarchical clustering was performed on same mid-point converted percent cover floristic data using the unweighted pair-group method (UPGMA) (Sokal & Michener 1958). The distance measure used was Bray-Curtis (Bray & Curtis 1957).

Dendrograms were generated from the cluster analysis as a visual representation of the binary tree structure. A level in each hierarchy was sought where floristic groups could be defined robustly with respect to floristic composition, vegetation structure and group indicator species. Floristic groups were recognised by drawing a vertical line through the dendrogram at a consistent point in the scaling of the fusion history using the Wishart (1969) objective function. Species fidelity with floristic groups was assessed using indicator species analysis (Dufrene & Legendre 1997). Relative abundance in floristic groups was defined as the average abundance of a given species in a floristic group divided by the average abundance of that species across all floristic groups, expressed as a percentage. Indicator values were calculated and a Monte Carlo randomisation test of significance applied to test the observed maximum indicator values for each species against the indicator value in all other groups. The randomisation test was run 10,000 times. Multivariate analyses were implemented in PC-ORD v. 6.08 (McCune & Mefford 1999). The results of the indicator species analysis were presented only for species with a relative frequency of >50%.

Results

Distribution

Cyathea cunninghamii is the more widespread taxon, being distributed from south-east Queensland to southern Tasmania (Figures 3a, 3b), while *Cyathea* x *marcescens* is limited to a subset of this area from East Gippsland to southern and eastern Tasmania (Figures 3a, 3b). Both taxa have a near-coastal distribution with more than 40% of the populations occurring within 5 km. of the coast (Figure 4). The populations furthest from the coast include those at Errinundra National Park in Victoria and Lamington National Park in Queensland. The altitudinal distribution of both taxa (median = 288 m) is indicative of the primary habitat being sub-coastal hinterland and escarpment forests (Figure 5), the exception being the higher altitude populations at Errinundra National Park in eastern Victoria and Lamington National Park in south-east Queensland. The core areas of distribution are the escarpment ranges of south and central Gippsland and the Otway Ranges of Victoria. The primary outlier population of *Cyathea cunninghamii* is in Lamington National Park in south-east Queensland, approximately 1000 km north of the nearest population of *Cyathea cunninghamii* at Nadgee in south-eastern New South Wales.

Population sizes

There are very few populations of either *Cyathea cunninghamii* or *Cyathea* x *marcescens*. The total number of populations for *Cyathea cunninghamii* and *Cyathea* x *marcescens* was estimated at 117 and 36 respectively, with a median population size of 3 individuals for *Cyathea cunninghamii,* and 4 individuals for *Cyathea* x *marcescens,* and an estimated total of 919 and 221 individuals respectively (see Tables 1 & 2). Based on the number of documented local population extinctions and the extent of land use change in those regions where both taxa occur, these numbers are significantly less than those (3500 and 730 mature individuals respectively) that have been estimated for prior to European settlement in Australia (Table 2b).

The largest populations of both *Cyathea cunninghamii* and *Cyathea* x *marcescens* occur in Tarra Bulga National Park in South Gippsland Victoria with an estimated 200 adult individuals of *Cyathea cunninghamii* (Ashwell 1991) and at least 50 adult individuals of *Cyathea* x *marcescens* (Healey, K., 22 June 1953, MEL 2152284A, in correspondence dated 12 July 1953 to J.H. Willis attached to sheet, cited by Bryant 2010). The next most populous regions are the Otway Ranges and East Gippsland, Victoria. The largest number of populations of both taxa is in the Otway Ranges, Victoria (Table 2) where they are found in steeply incised wet sclerophyll and rainforest habitats in various national parks and associated reserves. In East Gippsland both taxa are

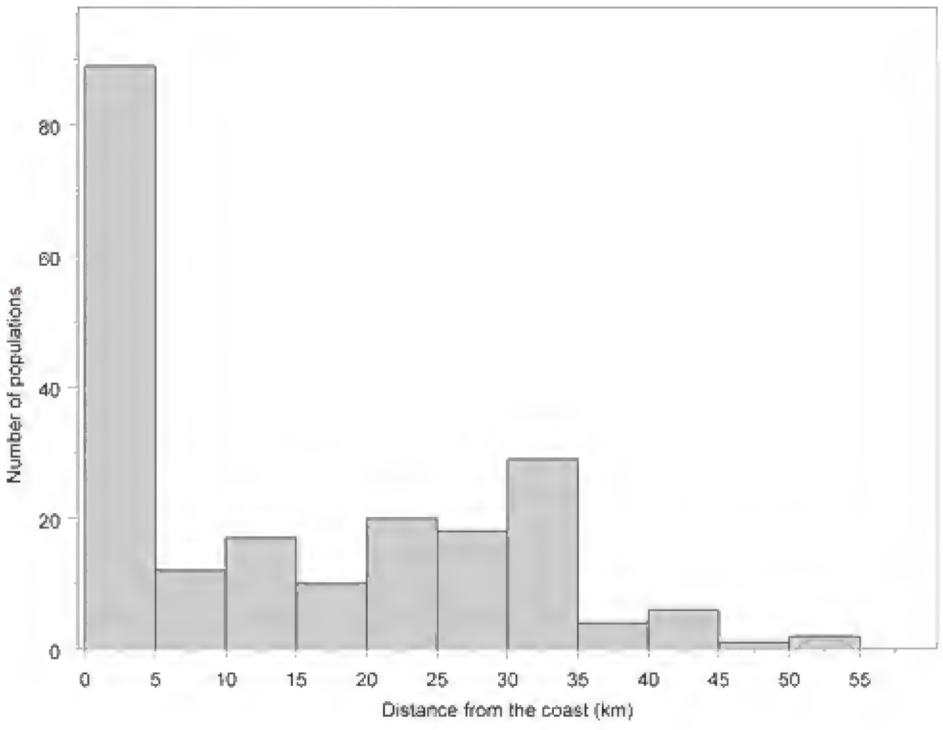

Fig 4. The near coastal distribution of 223 spatially distinct populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout their range in eastern Australia. Over 40% of the extant populations of both taxa occur within 5 km of the coast

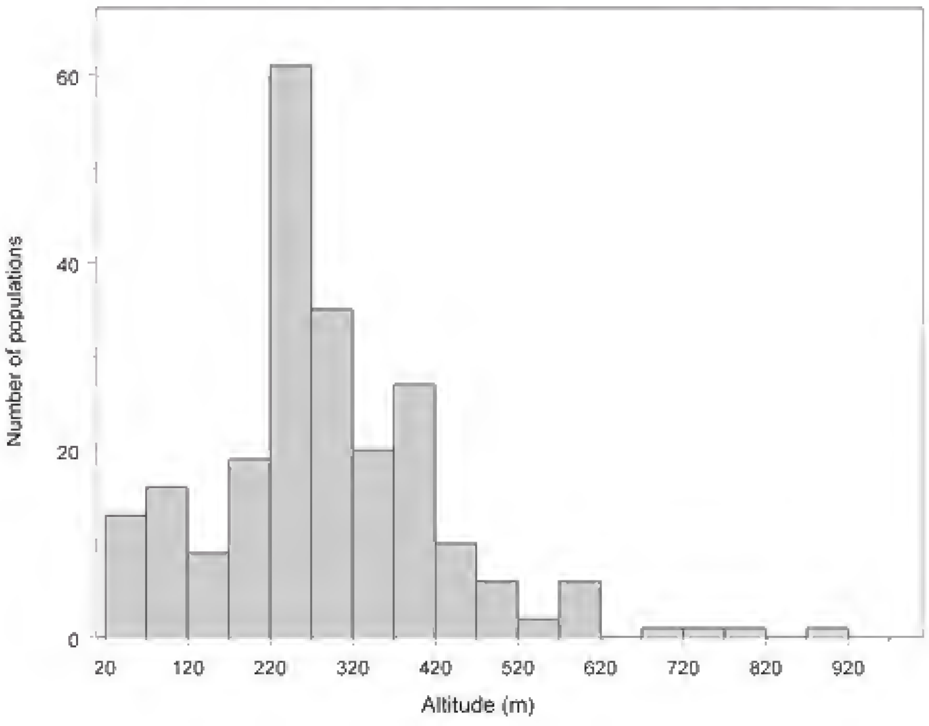

Fig. 5. The altitudinal distribution of the 223 spatially distinct populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout their range in eastern Australia. The median altitude is 288 m.

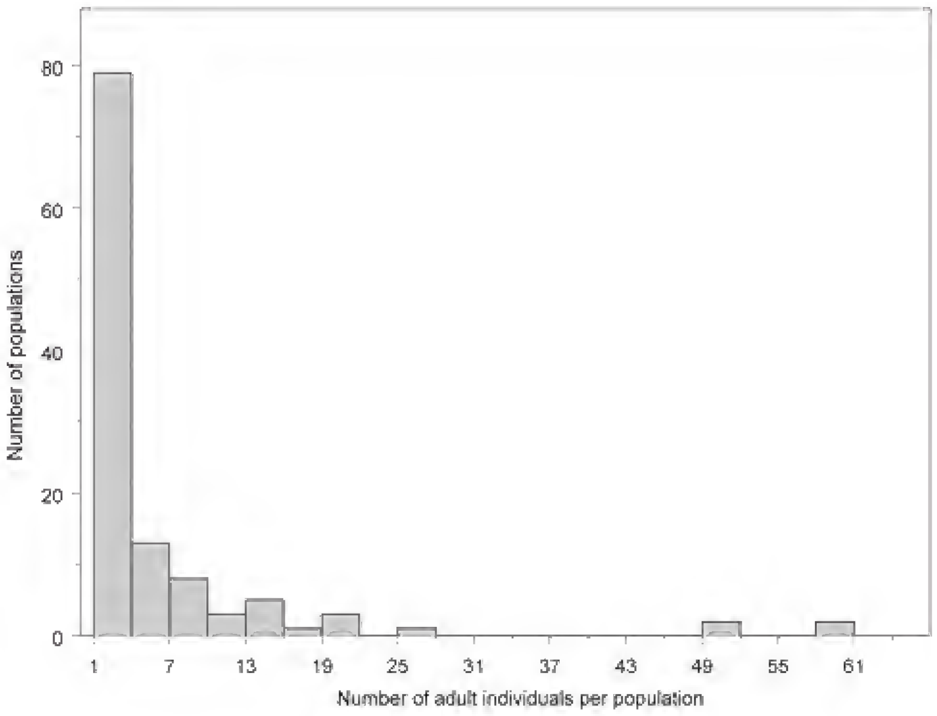

Fig. 6a: Distribution of *Cyathea cunninghamii* population sizes across the species range (n=117). The single largest population estimated to include 200 individuals at Tarra-Bulga National Park is excluded to maintain a comparable x-axis scale to Figure 6b.

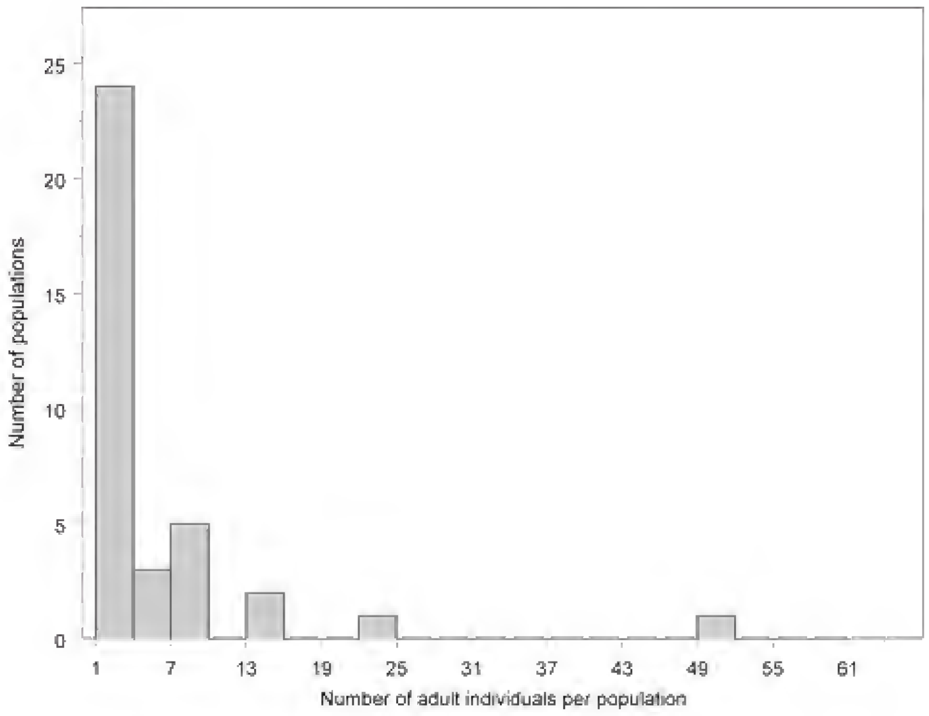

Fig. 6b: Distribution of *Cyathea* x *marcescens* population sizes across the taxon range (n=36).

widely distributed in coastal (e.g. Mallacoota and the Howe Ranges), near-coastal and escarpment forests, with the largest populations located in the Goolengook River catchment of Errinundra National Park (Lobert et al. 1991). In spite of the large area of potential habitat (wet sclerophyll forest, fern gullies and rainforest) in the Victorian central highlands, there is only a single cultivated *Cyathea cunninghamii* recorded beside a walking track at Badger (Coranderrk) Creek on land managed by Melbourne Water. This individual was reportedly planted prior to 1981 (R.L. Hill pers. comm. 1989). In New South Wales, *Cyathea cunninghamii* is known from a single plant in Maxwell's Flora Reserve in Nadgee State Forest.

Across the 117 known populations of *Cyathea cunninghamii,* more than 60% had five or less individuals (Table 2, Figure 6a). Similarly, population estimates for 36 populations of *Cyathea* x *marcescens* indicate that more than 70% had five or less individuals (Table 2, Figure 6b).

Repeated population surveys at key sites have permitted examples of population decline, increase and local extinctions to be documented for both taxa (Table 3). The majority of cases involve documented declines and local extinctions following habitat modification and land clearing for agriculture, although stochastic events including flash flooding and wind storm damage can be locally significant. The only known example of a population increasing in number is at Kallista, Dandenong Ranges National Park in Victoria, in an area which has not been subject to wildfire since 1939. In this case the population estimates date from 1879 to 2012 with the 2012 population of both taxa comprising 36 adult individuals.

Habitat preferences

The classification of 119 sites and 170 species was truncated at the six group level in the fusion history where six vegetation communities were recognised (Figure 7). These include: Group 1 – Wet sclerophyll Forests and Fern gullies; Group 2 – Warm and Cool Temperate overlap Rainforest; Group 3 – Cool Temperate Rainforest; Group 4 – Lowland Wet Sclerophyll Forest; Group 5 – Lowland Damp Sclerophyll Forest and Rainforest Ecotones; Group 6 – Mid-elevation Damp Sclerophyll Forest and Rainforest Ecotones. The dominant floristic and habitat characteristics of these communities are summarised in Appendix 1 and by their relative species abundance scores in Appendix 2.

Seven sites were identified as being distinct but could not be described adequately with the available data and are annotated in the dendrogram as unclassified.

Two dimensional NMS ordination of full floristic composition of the 119 plots and 170 species for sites that included either

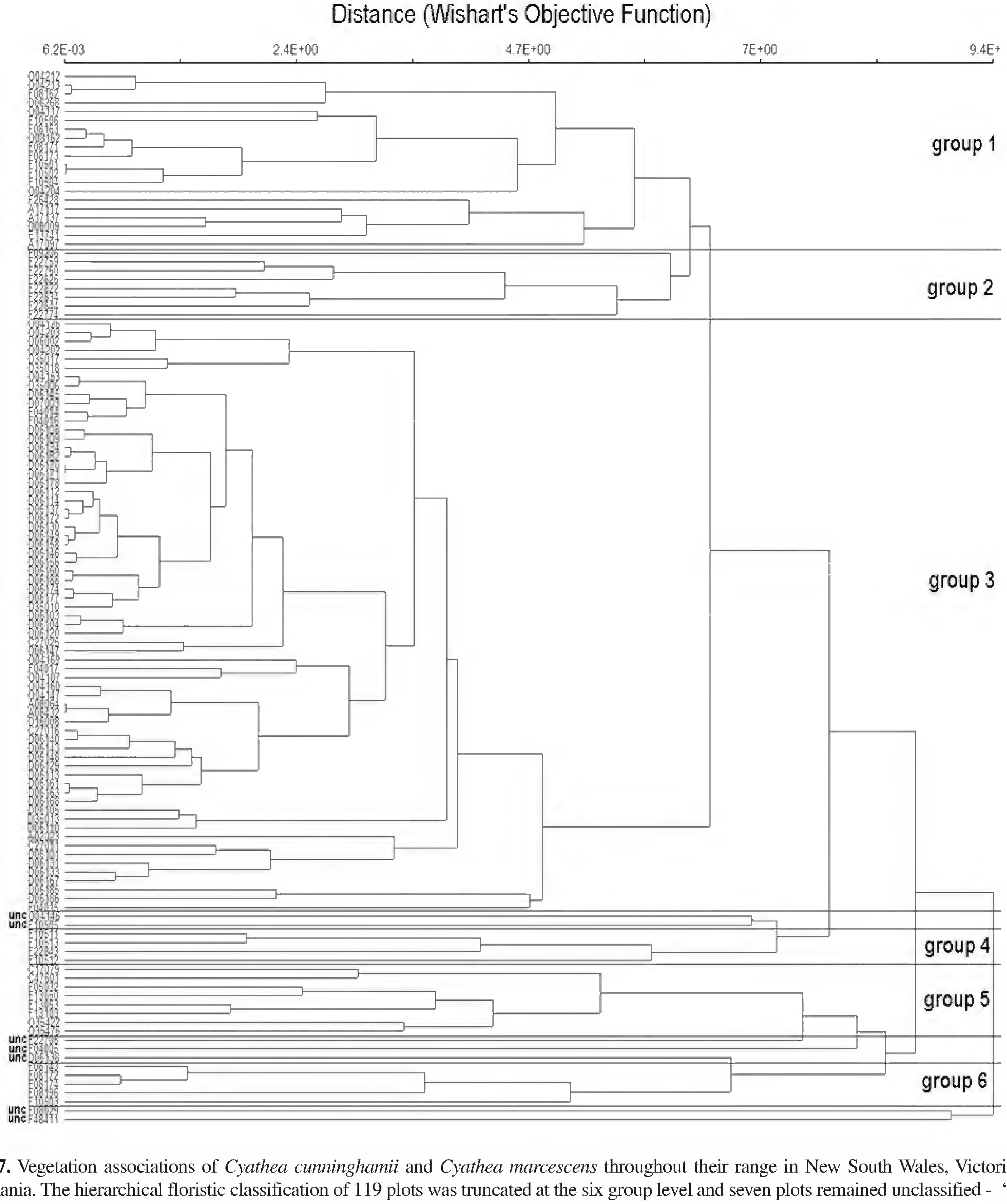

Fig. 7. Vegetation associations of *Cyathea cunninghamii* and *Cyathea marcescens* throughout their range in New South Wales, Victoria and Tasmania. The hierarchical floristic classification of 119 plots was truncated at the six group level and seven plots remained unclassified - 'unc'.

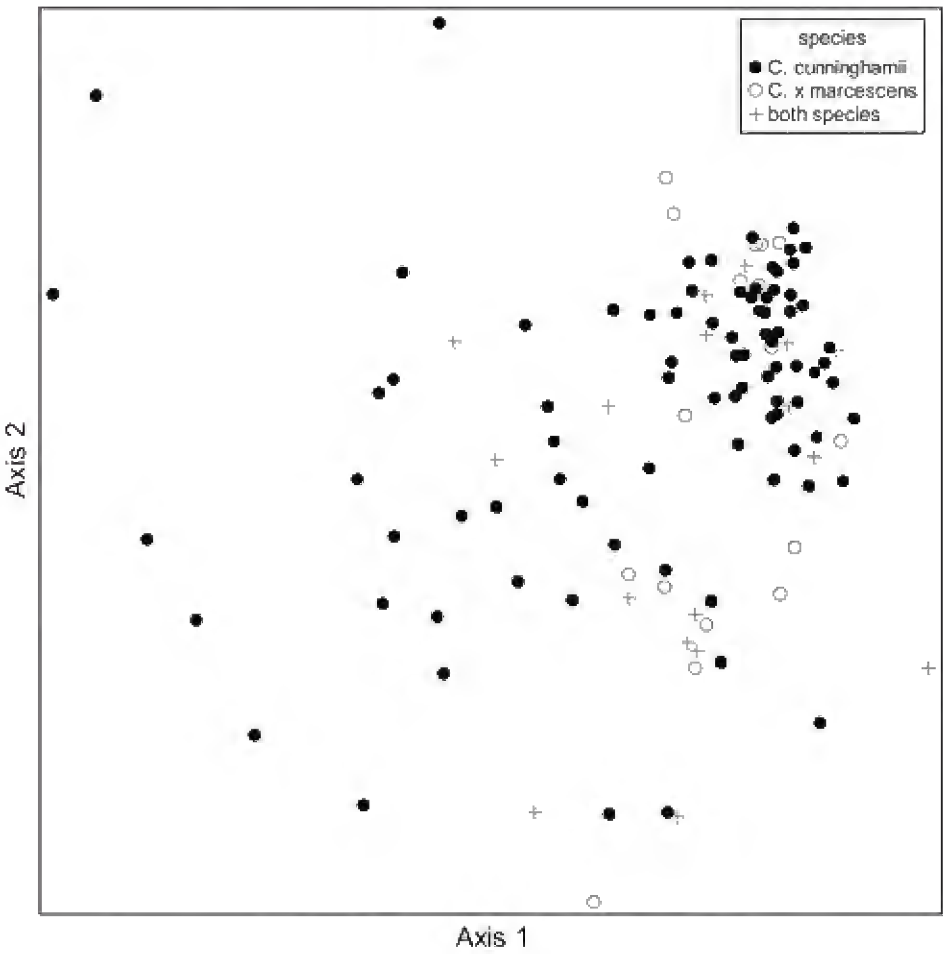

Fig. 8. Two dimensional NMS ordination of full floristic composition of 119 plots and 170 species for the six floristic groups shown in Figure 5. The site labels identify plots that included either *Cyathea cunninghamii*, *Cyathea* x *marcescens* or both taxa at the one location. A small number of sites include only the hybrid taxon *Cyathea* x *marcescens*.

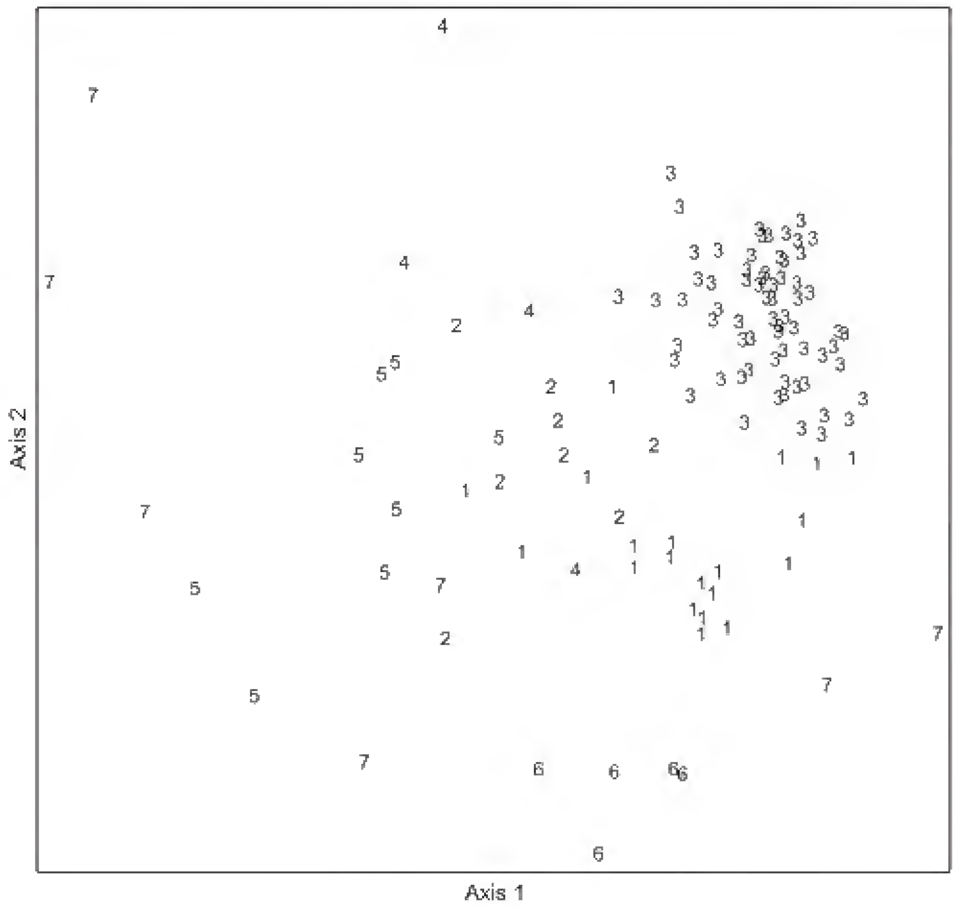

Fig. 9. Two dimensional NMS ordination of full floristic composition of 119 plots and 170 species. The six floristic groups are labelled 1-6 (Appendix 1-2); label '7' represents the unclassified ('unc') plots from Fig. 6. Minimum stress in relation to the two dimensional solution was 19.4.

Cyathea cunninghamii, or *Cyathea* x *marcescens,* or both, at the one location, is shown in Figure 8. Model fitting statistics for the ordination of floristic cover data are given in Table 3.

Two dimensional NMS ordination of full floristic composition of 119 plots and 170 species for the six floristic groups is shown in Figure 9.

Cyathea cunninghamii occurs widely across all geographic regions and environments from simple microphyll fern forest in south-eastern Queensland through both warm and cool temperate near coastal forest types in New South Wales, Victoria and Tasmania. *Cyathea* x *marcescens* is limited to wet sclerophyll forests and fern gullies, and mid-elevation East Gippsland damp sclerophyll forest and rainforest ecotones of Victoria, south-eastern New South Wales and Tasmania (Appendix 1). In Tasmania, the majority of extant sites occur within 3 km of the coast and between 20 to 150 m above sea level.

Cyathea cunninghamii occurs in each of the six recognised vegetation communities and *Cyathea* x *marcescens* occurs in all but one of these communities: Group 4 (Lowland Wet Sclerophyll Forest). The second parent species, *Cyathea australis*, occurs in all of the communities except one: Group 4 (Lowland Wet Sclerophyll Forest). Group 4 has only four sites, three of which are from southern Tasmania where *Cyathea australis* is infrequent (Appendix 1).

Floristics of populations from the Victorian Otway Ranges and South Gippsland regions were the most similar and homogeneous, while floristics of populations from East Gippsland were the most heterogeneous (Figure 10), being found across a broader suite of environments from gentle slopes of lowland valleys, to moderate to deeply incised gullies of headwater streams. The Goolengook populations of East Gippsland (Errinundra National Park) are unique in their association with rainforest with overlapping components of cool and warm temperate rainforest, a characteristic not found elsewhere in the Victorian populations except for the East Errinundra River section of Errinundra National Park.

Table 3. Model fitting statistics for the ordination of floristic cover data in two dimensions and coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space. Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes.

Axis	**r-squared**		**Minimum stress in real data**	**r-squared and % orthogonality with each axis**	
	increment	**cumulative**		**axis 1**	**axis2**
1	0.495	0.495	31.1	-	0.199, 96.0%
2	0.309	0.803	19.4	-	-

The single record of *Cyathea cunninghamii* in NSW is associated with *Eucryphia moorei* temperate rainforest. All other Victorian and Tasmanian populations are associated with cool temperate rainforest, wet forest, or in the case of lowland East Gippsland, warm temperate rainforest.

Discussion

Distribution

Fern distribution in Australia tends to be closely associated with the distribution of different forest types (Page & Clifford 1981), and this appears to be the situation with respect to the types of plant communities in which *Cyathea cunninghamii* and *Cyathea* x *marcescens* occur. The temperate rainforest and fern gully communities of Victoria and Tasmania, while not being as species rich in ferns as the tropical forests of north Queensland, are characterised by the presence of many individual ferns belonging to few species (Page & Clifford 1981). The typical eastern Australian fern gully dominated by *Dicksonia antarctica* and, to a lesser extent by *Cyathea australis,* is one example of this phenomenon. Within these fern gully associations, micro-habitat preferences can be identified from empirical evidence based on extensive field population surveys across the range of both taxa. While both taxa have distributions which initially appear to parallel the distribution of cool temperate rainforest and wet sclerophyll forest in Victoria, they are curiously absent from the extensive tracts of cool, wet sclerophyll vegetation in the Victorian central highlands. This is also the situation in Tasmania where most populations of *Cyathea cunninghamii* occur close to the coast, between 20 – 150 m above sea level (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011a). Factors controlling their distribution are difficult to determine because of the very small number of known populations across a geographic range extending from south-east Queensland to southern Tasmania and the ability of tree fern species for long distance spore dispersal (Brownsey 2001). However, the general consensus for tree ferns is that rainfall and temperature either at the continental, regional or local scale primarily influence their distribution (Brownsey 2001, Lehmann et al. 2002). In an area well known for its overlap of southern boundaries of many northern plant species and the eastern boundary of many southern and western plant species, the occurrence of a single adult *Cyathea cunninghamii* in New South Wales, only five kilometres directly north of the Victorian-New South Wales border in Nadgee State Forest, is both a significant extension of that species distribution and an example of the challenge in understanding the factors controlling the species distribution.

In order to determine which factors may control distribution, it may be more useful to examine the two taxa on a local scale. For example *Cyathea cunninghamii* may be locally plentiful in a particular fern gully in the Otway Ranges, but absent from many other seemingly suitable habitats elsewhere in the same region.

Undoubtedly, the characteristic feature of the ecology of both taxa is their micro-habitat preference for the stream banks of mountain forests, especially in areas of reliable, high rainfall (generally > 1200 mm) and high humidity. These stream banks may occur in a wide variety of floristic and structural vegetation communities, ranging from warm and cool temperate rainforests through to tall open forests and occasionally minor fern gullies of open forests. They include the type locality for *Cyathea* x *marcescens* in warm temperate rainforest, dominated by *Acmena smithii* and *Rapanea howittiana* at Alfred National Park in Victoria (Wakefield 1953) which is included in vegetation community six.

Ultimately, the distribution and survival of the hybrid *Cyathea* x *marcescens* is dependent on the presence of both parents, *Cyathea cunninghamii* and *Cyathea australis,* at the same location, with moist substrates suitable for spore germination, subsequent development of gametophytes, fertilization and growth of sporophytes. Field examination of a number of populations suggests that *Cyathea cunninghamii,* which has a requirement for a reliable and abundant water supply, is restricted to stream banks with a high water table. Preferred habitats are often in close proximity to waterfalls, (supposedly to benefit from increased humidity and higher light levels) and on shallow creek banks in upper catchments unlikely to be scoured by flash flooding. Early descriptions of the preferred habitat suggest that plants of *Cyathea cunninghamii* are to be found in ‘the coolest and deepest fern-gullies’ (Bond & Barrett 1934 p. 27) and in the ‘deepest, wettest part of the gully, with their roots almost in the water’ (Barfield 1974). Field observations also suggest the species preferred recruitment substrate is either open stream banks or cleared areas along walking tracks, consistent with the experimental evidence from New Zealand that the species high growth and mortality rates are linked to high photosynthetic rates (Bystriakova et al. 2011).

Cyathea australis, on the other hand, grows on a much greater range of substrates, in a much wider array of habitats, tolerating hotter and drier sites with higher light levels (Volkova et al. 2010a) than the moist, shaded creek banks on which *Cyathea cunninghamii* is found. *Cyathea* x *marcescens* grows on intermediate sites between *Cyathea cunninghamii* and *Cyathea australis* (Garrett 1996, Peacock pers. obs.).

The habitat preferences of *Cyathea cunninghamii* in New Zealand reflect those in Australia: damp gullies or rivers within low altitude forests on young soils (eg Bystriakova et al. 2010), protected from drought and cold. Brownsey (1979) suggested that the relative susceptibility of *Cyathea cunninghamii* to drought when compared to other *Cyathea* species, may be a limiting factor in its distribution in New Zealand. The species is almost absent from drier eastern side of both New Zealand islands, occurring up to 1000 m in elevation, (approaching the altitudinal limit of the species in Queensland) and is most commonly found in near-coastal habitats up to 50 km from the coast.

Population sizes

The limited size of most extant populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* is not considered to be a recent phenomenon that might be associated with urban sprawl or agricultural or plantation development. Early accounts refer to *Cyathea cunninghamii* as a 'rather scarce fern' (Pitcher 1913 p. 10), 'now very uncommon in Tasmania' (Wakefield 1975) and in reference to the first collection of *Cyathea* x *marcescens* in 1880 from the Otway Ranges as 'only to be found occasionally' (Wakefield 1945), indicating that small population sizes are a characteristic of both taxa. In New Zealand, similar references report *Cyathea cunninghamii* as being 'one of the least plentiful of our tree-ferns… scattered sparsely along some of the gullies…only three or four specimens in the vicinity' (Crookes & Dobbie 1963) and 'only locally common despite its wide distribution' (Brownsey 1979).

Given that *Cyathea cunninghamii* appears to be a naturally uncommon species, it is inevitable that *Cyathea* x *marcescens* will also be of very limited distribution, since *Cyathea cunninghamii* is one of its parents. However, the very occurrence of *Cyathea* x *marcescens* in a mixed population may be contributing to the paucity of *Cyathea cunninghamii* individuals. In populations where adult plants of *Cyathea australis* greatly outnumber those of *Cyathea cunninghamii*, there will be a similar discrepancy in the number of gametophytes of each species. Hence there will be limited opportunities for fertilisation between gametophytes of *Cyathea cunninghamii.* Those opportunities will be limited still further if significant numbers of gametophytes are 'wasted' in cross-fertilisation with *Cyathea australis* when its gametophytes are present in overwhelming numbers. In other words, every adult individual of *Cyathea* x *marcescens* represents the potential loss of at least one individual of *Cyathea cunninghamii*, and possibly more, since hybrids are less likely to develop than the parent species as a result of genetic imbalance.

Threats

Inferring threat levels and the probability of population extinction is challenging in the absence of large data sets and independent, systematic observations. While approaches using collection data have been trialled (Burgman et al. 1995) their implementation requires care because their statistical basis assumes the chance of a species being collected does not change over time and the true chance of being collected reflects the relative abundance of the species. In the case of *Cyathea cunninghamii* and *Cyathea* x *marcescens,* the added complication exists that many of the earliest collections had imprecise localities recorded and a contemporary search of the population is therefore difficult to plan. Secondly, methods are now needed to merge and perhaps weight different sources of distributional data for both taxa. Herbarium collections have the greatest taxonomic reliability. However from the late 1980s, databased floristic plot survey records surpassed collection data in quantity and extent in Victoria and consequently form an important source of data in inferring threat status. Threats to both taxa have been extensively communicated in both Tasmania (Forest Practices Authority 2012, Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011c) and Victoria (Gutowski 1996, Department of Sustainability & Environment (undated), Department of Natural Resources & Environment 2002) as part of legislated threatened species review programs. Examples of the range of identified threats and resulting local population extinctions or decline Victoria and Tasmania are included in Table 4.

Non-anthropogenic threats

The very low population estimates for *Cyathea cunninghamii* and *Cyathea* x *marcescens* in regional Victoria and Tasmania highlight the sensitivity of both taxa to stochastic events such as flood, fire, drought and storms. Floods are one of the key natural limitations to their distribution. Stream bank scouring as a result of flash flooding appears to be one of the most destructive factors in limiting recruitment of *Cyathea cunninghamii.* Neither *Cyathea cunninghamii* nor *Cyathea* x *marcescens* is known to grow on the banks of larger streams and rivers subject to peak flows exceeding normal river bank levels. Garrett (1997) reported that the 1988 floods in northern Tasmania destroyed mature specimens of *Cyathea cunninghamii* and one specimen of *Cyathea* x *marcescens.* Disturbance to headwater catchment areas, for example for forestry, agriculture or road construction, that modifies stream flow and increases scouring and sediment deposition, may have implications for the survival of *Cyathea cunninghamii* and possibly *Cyathea* x *marcescens,* both in terms of loss of mature specimens and in the negative impact on regeneration.

Wildfire has been identified for over a century as a threat to populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens.* Descriptions of the effects of wildfires were frequently graphic; '*disastrous fires, especially the great holocaust of January 1951* (in Wilsons Promontory National Park), *have reduced the occurrence of some rare kinds almost to vanishing point. The elegant Slender Tree-fern (*Cyathea cunninghamii*, Victoria's tallest fern), … are now extremely rare, localised and very seldom observed*' (National Parks Authority 1969 p. iv). Later references to *Cyathea cunninghamii* include populations becoming 'uncommon and vanishing as the result of fires' (Willis 1970) and 'because of fires and forest clearing is disappearing' (Barfield 1974). However, some early observers did not consider wildfire to be a threat to populations of either *Cyathea cunninghamii* or *Cyathea* x *marcescens;* for example, N.A. Wakefield (cited in Hunter 1942) stated that "*both areas* (Mt Drummer) *have been severely burned several times, and each time the patches of 'jungle' along the creeks have escaped and the ferns survived*". More recent observations indicate that these same populations which escaped the 1939 fires (Wakefield 1967) did not survive the 1983 Cann River wildfires and both taxa now only survive in adjacent rainforest stands.

Table 4. Examples of population declines and local extinctions for *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout their range in Victoria and Tasmania.

Species	Location	Initial population estimate and (date)	Most recent population estimate and (date)	Reason for change
Cyathea cunninghamii				
	Main Creek, southeast of Arthurs Creek Mornington Peninsula (Vic.)	unknown (1883)	Locally extinct by 1949 (Wakefield & Willis 1949)	agricultural land clearing
	Mt Burnett, Upper Pakenham (Vic.)	1 (date unknown)	Locally extinct (1989)	habitat modification
	Berwick (Vic.)	4 (1989)	Locally extinct (1999)	habitat modification
	Deadlock Creek Gorge, near Yarragon (Vic.)	3 (1960s)	Locally extinct (1989)	softwood plantation development
	Mount Disappointment Reference Area Plenty River headwaters Kinglake National Park (Vic.)	1 (1980s)	Locally extinct (2011)	severe wildfire
	Corinna, Pieman River (Tas.)	1 (1986)	Locally extinct (2011)	tree fall
	Grassy River King Island (Tas.)	5 (1990)	1 (2011)	falling trees during storms
	Circular Head district (Tas.)	Unknown (1940s)	Locally extinct (2011)	habitat loss, adjacent selective harvesting
Cyathea x *marcescens*				
	Grassy River King Island (Tas.)	5 (1990)	1 (1996)	falling trees during storms
	Lower Marsh Creek Forest Reserve (Tas.)	60 (1982)	24 (1986)	flash flooding
	Mt Drummer section Alfred National Park 'below the Springs' (Vic.)	(1941)		lectotype location, presumed lost during 1983 wildfires although persists nearby in unburnt rainforest

In February 2009, severe bushfires spread through Kinglake National Park, decimating populations of many mesic dependent ferns and their rainforest habitats. Just & Beardsell (2011) predicted that many fern species would be unlikely to recover in the near future because of the destruction of canopy cover and deep humus on the forest floor, and the replacement of rainforest with drier, more fire prone elements of sclerophyll forest. One such local extinction was the single known specimen of *Cyathea cunninghamii* observed by Cam Beardsell in 1988 in the headwaters of the Plenty River East Branch in the Mt Disappointment Reference Area of Kinglake National Park. The single specimen was associated with *Nothofagus cunninghamii* and *Atherosperma moschatum* in a highly protected gully which had escaped all previous known fires since 1729 (Ashton 2000).

The size and height of tree ferns can increase their extinction or disturbance risk (Mehltreter 2010) and for *Cyathea cunninghamii* its relatively large crop of fronds and tall narrow caudex increases its vulnerability to high winds. Mature specimens have been brought down by high winds in the Eaglehawk Neck area of Eastern Tasmania (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011a) and both *Cyathea cunninghamii* and *Cyathea* x *marcescens* have had their crowns blown out where populations were adjacent to clear felled forest in the Otway Ranges, Victoria (Roberts 1991). During the period 1990 – 1996, a number of specimens of *Cyathea* x *marcescens* were destroyed by falling trees following storms, for example on Grassy River at King Island and Lower Marsh Creek Tasmania (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011b).

Anthropogenic threats

Land clearance for agricultural development and associated burning probably represents the most significant historical threat to populations of the two taxa. In addition to clearing, other potential threats include: construction of farm roads, buildings and dams that may adversely affect hydrology; cultivation of crops with the potential to increase downstream siltation; trampling by stock; introduction of weed species; and use of pesticides and fertilizers (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011c). One of the largest known populations of *Cyathea cunninghamii* in Victoria occurs in the Kallista area near Melbourne, an area which is coming under increasing pressure from suburban development, recreation demands and weed invasion. The main threat for this population is weed invasion, particularly species that colonise the caudex such as ivy (*Hedera helix),* or species such as Wandering Trad (*Tradescantia fluminensis*) that form a dense cover over creek banks where most spore germination and growth of young sporophytes occurs.

The expansion of the dairy industry and gold prospecting in the nineteenth century, and the development of broad scale plantation estates in areas such as central Gippsland during the 1960s – 1970s (e.g. Deadlock Creek Gorge, Yarragon), probably led to the local extinction of smaller populations in Victoria and in northern Tasmania. Geographically isolated populations were most prone to local extinction, for example the Main Creek population at Arthurs Seat on Victoria's Mornington Peninsula (J.M. Baldry, 1883, MEL 224441A) which is extinct as a result of agricultural land clearing (Wakefield & Willis 1949). Land use intensification saw further populations become locally extinct in the 1970s in south Gippsland (Dumbalk east of Leongatha) which, in this case, reportedly also resulted in the sale of tree ferns to the horticultural trade during clearing (Scarlett 1980). The reduction of available habitat for tree fern species in Victoria is not a recent phenomenon, with Robbins (1945) referring to fern gully habitats as 'fast disappearing'.

Forest management practices (timber harvesting and fuel reduction) have the potential to adversely affect populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens.* Presently, in all jurisdictions, both taxa are now protected via threatened species planning provisions and forest practices codes, although the strength of these approaches relies on the population being identified during the pre-harvesting planning process. Whether forest management has led to the diminution of the range of either taxon is debatable; several action statement reviews have argued this to be the case (e.g. Gutowski 1996), however direct evidence has often been lacking due to the absence of targeted population monitoring. In addition to possible changes to microclimate and hydrology, timber harvesting has the potential to increase exposure to high winds and consequent tree fall. The single known plant of *Cyathea cunninghamii* at Nadgee State Forest in NSW exists in a minor gully whose canopy of *Eucryphia moorei* rainforest has structurally deteriorated as a result of dieback from exposure and canopy branch blowout. The deterioration of this small rainforest stand is most likely a response to intensive harvesting without adequate buffering. The adjacent forest compartment was burnt by wildfire in 1952, harvested for sawlogs in the 1960s, harvested again for sawlogs and pulpwood in 1975–76 and burnt by a wildfire in 1980 (Forestry Commission of NSW 1988). The dedication of the flora reserve in 1988 over this remnant rainforest stand has focussed management efforts on fire protection.

Post-harvest burning to promote overstorey regeneration may pose a threat if poorly implemented on rainforest boundaries (Otway Ranges Environment Network 2004). The low frequency of hazard reduction burning and minimal disturbance from timber harvesting may have contributed to the survival of both taxa at several localities in the Goolengook catchment East Gippsland (Errinundra National Park). Similarly in Tasmania, there is the potential for both taxa to be affected by wildfires or from poorly implemented post-harvest burning (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011c).

The illegal taking of tree ferns for horticultural purposes has been a long term problem in Australia (Robbin 1985, Hodgson 2007) and has the potential not only to decimate populations but also to damage habitats from which the tree ferns have been taken. Permits to take tree ferns are now strictly controlled, for example: Department of Sustainability & Environment (Victoria) Application for a Permit to Take Protected Flora (2008); and the Forest Practices Authority (Tasmania) (2011) regulations. The collection of *Cyathea cunninghamii* for horticultural use (e.g. Pitcher 1913) is now unlikely and so is the harvesting of the starchy caudex apex for baiting animal traps (Bond & Barrett 1934). In Victoria, wild grown *Cyathea cunninghamii* has not been traded horticulturally since the early 1980s (Peacock pers. obs).

Long term human induced climate change is predicted to lead to a reduction in available habitats for *Cyathea cunninghamii* and *Cyathea* x *marcescens* in southern Australia as the climate becomes both warmer and drier. The Tasmanian, Victorian and NSW populations at present are located in the near-coastal ranges where climate change and increased climate variability have the potential to alter the extent of their suitable habitat. It may be possible to use the existing climate change scenarios to predict areas of potentially suitable habitats at higher elevations.

Conservation management

Cyathea cunninghamii and *Cyathea* x *marcescens* are variously considered in Australia as rare, vulnerable or endangered (Appendix 3). In New Zealand, *Cyathea cunninghamii* is not threatened (de Lange et al. 2009). The status of both taxa has not been assessed or decided by the Commonwealth Threatened Species Scientific Committee and therefore neither has been listed under the national Environment Protection and Biodiversity Conservation Act 1999. In view of the relative isolation of populations, and the small number of individuals that comprise each population, urgent consideration should be given to the nomination of *Cyathea cunninghamii.* The situation for *Cyathea* x *marcescens* is somewhat different. If locations where populations of *Cyathea cunninghamii* grow in close proximity to *Cyathea australis* are protected, there will always be the potential for spontaneous reproduction of hybrid offspring of *Cyathea* x *marcescens.*

The management, protection and recovery of existing populations of tree ferns in Tasmania has been comprehensively documented in the Flora Recovery Plan: Threatened Tasmanian Ferns (Threatened Species Section 2011c). In Tasmania the management objectives for *Cyathea cunninghamii* are to minimise the probability of extinction of subpopulations by ensuring habitat protection. This includes specific fire exclusion provisions, survey of surrounding areas for possibility of locating more populations in habitats with comparable characteristics, investigation of propagation techniques to repopulate areas from where the species has disappeared or to supplement existing populations. The success of these measures, in particular the provisions of the Forest Practices Code in Tasmania, has been evident in the recent discovery of new large populations of both taxa (e.g.

Leaman 2011) during pre-harvest planning. The survival of the F1 hybrid, *Cyathea* x *marcescens* requires the protection of locations where both parents, *Cyathea cunninghamii* and *Cyathea australis,* grow in close proximity to each other and where conditions for reproduction are favourable.

The relationship between *Cyathea cunninghamii, Cyathea australis* and their hybrid offspring *Cyathea* x *marcescens* appears to mirror the relationship reported elsewhere between parent fern species and their hybrids (Brownsey 1981, Smith & Grayum 1988, Kentner & Mesler 2000). In these instances one parent (like *Cyathea cunninghamii*) was restricted to moist, shady sites, the other (like *Cyathea australis*) able to colonise a much more varied range of sites, but generally those with lower moisture and higher light levels; taxa identified as hybrids (*Cyathea* x *marcescens*) occupied intermediate sites. Kentner & Mesler (2000) considered that this distribution of hybrids was explained as the result of environmentally mediated natural selection and only individuals with genotypes suited for various microclimates survived to reproductive maturity.

While it is clear that populations of both taxa have declined over the last two hundred years, the magnitude of this decline is difficult to quantify with several of the largest known populations only being discovered in the last twenty years. Additionally the rate at which new populations have been recorded has declined since the 1990s when remote forest areas were being actively surveyed for biodiversity prior to timber harvest planning.

Until recently, positive identification of young *Cyathea* species was not possible until plants reached maturity. By combining morphological characters together with allozyme and chloroplast DNA markers, using the techniques of Kentner & Mesler (2000), it should be possible to identify young sporophytes of both parent species and hybrid offspring. Additionally, recently developed tissue culture techniques (Fernandez et al. 1993, Goller & Rybczyński 2007, Higuchi et al. 1983, Kuriyama et al. 2004) may be useful in the formulation of techniques for the propagation of both *Cyathea cunninghamii* and *Cyathea* x *marcescens*, to ensure their survival. However, as long as locations where both *Cyathea australis* and *Cyathea cunninghamii* grow together are protected, it is highly likely that hybrid offspring (*Cyathea* x *marcescens*) will continue to occur spontaneously, as they do under conditions of controlled propagation using spores of both parents (Hill 1984). The importance of the co-occurrence relationship between *Cyathea cunninghamii* and *Cyathea* x *marcescens* was perhaps recognised as early as 1880 by a simple note accompanying a herbarium specimen that ‘they both grow in company with one another’ (MEL 2152287A 01/04/1880, Cape Otway Range, coll. Marriner, G.H. cited by Wakefield 1945 p. 126).

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Appendix 1 Summary of floristic and habitat information for six vegetation communities (groups) with which tree ferns *Cyathea cunninghamii* and *Cyathea* x *marcescens* are associated. *Cyathea cunninghamii* was recorded in all six vegetation communities; *Cyathea* x *marcescens* was recorded in two: Group 1 and Group 6.

	No. of Sites	**Distribution**	**Altitude m (mean, se)**	**Slope, aspect**	**Landform**	**Mean species richness per plot (0.09 ha)**	**Dominant Species**
Group 1							
Wet sclerophyll Forests and Fern gullies **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	20	**Victoria:** Otway Ranges, South, Central and East Gippsland, Yarra Ranges, Badgers Creek Healesville	373 (27)	gentle to steep slopes, southerly aspect	Creeks and minor river banks	25	**Trees:** *Eucalyptus fastigiata*, *E. regnans*, *Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon*, *Atherosperma moschatum*, **Shrubs:** *Coprosma quadrifida*, *Dicksonia antarctica* **Ground Cover:** *Lastreopsis acuminata*, *Polystichum proliferum*
Group 2							
Warm and Cool Temperate overlap Rainforest **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	8	**Victoria:** Wilsons Promontory National Park, Errinundra National Park	186	Flat to gentle slopes, nil aspect	Boggy stream terraces, stream confluences	35	**Trees:** *Acmena smithii*, *Atherosperma moschatum*, *Eucalyptus obliqua*, *Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon*, *Pomaderris aspera* **Shrubs:** *Coprosma quadrifida*, *Dicksonia antarctica*, *Zieria arborescens* subsp. *arborescens* **Ground Cover:** *Lepidosperma elatius* *Pellaea falcata* s.l., *Polystichum proliferum*
Group 3							
Cool Temperate Rainforest **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	67	**Victoria:** Otway Ranges, South Gippsland Tarra-Bulga National Park	287	Moderate to steep slopes, southerly aspect	Streams in headwaters of minor catchments	25	**Trees:** *Atherosperma moschatum*, *Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon*, *Pittosporum bicolour* **Shrubs:** *Dicksonia antarctica*, *Hedycarya angustifolia* **Groundcover:** *Blechnum wattsii*, *Polystichum proliferum*
Group 4							
Lowland Wet Sclerophyll Forest **Includes:** *C. cunninghamii*	4	**Victoria:** Wilsons Promontory National Park **Tasmania:** Eaglehawk Neck, Hastings Caves	72	Gentle slopes, nil aspect	Minor gullies	26	**Trees:** *Eucalyptus obliqua*, *Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon*, *Bedfordia salicina*, *Olearia argophylla*, *Pomaderris apetala* **Shrubs:** *Tasmannia lanceolata* **Ground Cover:** *Blechnum wattsii* *Polystichum proliferum*,

Group 5							
Lowland Damp Sclerophyll Forest and Rainforest Ecotones **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	8	**Victoria:** East Gippsland Croajingalong National Park Mt Drummer Alfred National Park	267	Moderate slopes, variable aspects incised gullies	Moderate to deeply	50	**Trees:** *Acmena smithii, Eucalyptus cypellocarpa* **Small Trees:** *Pomaderris aspera, Rapanea howittiana* **Shrubs:** *Bedfordia arborescens, Cyathea australis* **Ground Cover:** *Blechnum cartilagineum, Lastreopsis acuminata*
Group 6							
Mid-elevation Damp Sclerophyll Forest and Rainforest Ecotones **Includes:** *C. cunninghamii* *C.australis* *C.* x *marcescens*	5	**Victoria:** East Gippsland Errinundra National Park (Goolengook) **New South Wales:** Maxwell Flora Reserve Nadgee State Forest	348	Moderate slopes, variable aspects	Minor headwater gullies	27	**Trees:** *Acmena smithii, Eucalyptus fastigata, Eucryphia moorei* **Small Trees:** *Acacia melanoxylon, Pomaderris aspera* **Shrubs:** *Cyathea australis, Rubus moluccanus* var. *trilobus* **Ground Cover:** *Blechnum patersonii, Lastreopsis acuminata*

Appendix 2 Relative percent abundance of species present in each of six vegetation groups, expressed as the average abundance of a given species in a given group of plots over the average abundance of that species in all plots (following Dufrêne & Legendre, 1997).

Group 1 Wet Sclerophyll Forests and Fern gullies; Group 2 Warm and Cool Temperate Overlap Rainforest; Group 3 Cool Temperate Rainforest; Group 4 Lowland Wet Sclerophyll Forest; Group 5 Lowland Damp Sclerophyll Forest and Rainforest Ecotones; and Group 6 Mid-elevation Damp Sclerophyll Forest and Rainforest Ecotones

The p value indicates the significance of the species maximum indicator value following a Monte Carlo randomisation test. * indicates introduced species

Taxon	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	p value
Acacia cognata					100		
Acacia dealbata	52		48				
Acacia frigescens	100						
Acacia melanoxylon	11	28	16	22	22	1	
**Acer pseudoplatanus*	100						
Acmena smithii		30			56	13	0.0014
**Anthoxanthum odoratum*			100				
Asplenium appendiculatum subsp. *appendiculatum*				88	12		
Asplenium bulbiferum subsp. *gracillimum*	10	16	16	4	27	27	
Asplenium flaccidum subsp. *flaccidum*			75		25		0.0070
Atherosperma moschatum	15	38	30	17			
Austrocynoglossum latifolium			100				
Australina pusilla subsp. *muelleri*	28	6	24		17	25	
Bedfordia arborescens	5	31			61	3	0.0104
Bedfordia salicina				100			0.0012
Blechnum cartilagineum					98	2	0.0001
Blechnum chambersii	6	22	48	18	1	4	0.0245
Blechnum fluviatile	27	6	55	12			0.0223
Blechnum minus	100						
Blechnum nudum	4	2	13	67	13	2	0.0058
Blechnum patersonii subsp. *patersonii*	15	17	4		30	35	0.0476
Blechnum wattsii	3	15	42	23	17		0.0129
Calochlaena dubia		81			19		
Cardamine hirsuta	100						
Carex appressa	20	33	37			10	
Cassinia aculeata					100		
Cassinia longifolia	100						
Cassinia trinerva	12	8	8		59	13	0.0363
Celastrus australis					100		0.0058
**Cephalomanes caudatum*		12			88		0.0115
Cissus hypoglauca	2				89	9	0.0001
Clematis aristata	19	46	12	18	6		0.0213
Clematis glycinoides var. *glycinoides*	8				77	15	0.0024
Coprosma quadrifida	10	38	18	10	21	3	0.0411
Correa lawrenceana var. *latrobeana*			3		97		0.0003
Crepidomanes venosum	7	40	18	7	18	11	
Ctenopteris heterophylla	6	32	30	32			
Cyathea australis	13	9	3		63	13	0.0022
Cyathea cunninghamii	10	17	22	17	20	14	
Cyathea leichhardtiana					100		
Cyathea x *marcescens*	31	6	17		6	39	0.0312
**Dactylis glomerata*	100						
Dianella tasmanica	32		6		62		
Dicksonia antarctica	19	18	29	9	18	6	0.0001
Diplazium australe	6		27		46	21	0.0235
Elaeocarpus reticulatus		23		10	49	17	0.0249
Eucalyptus cypellocarpa	32	11			58		0.034
Eucalyptus fastigata	14				52	34	
Eucalyptus obliqua		10		88	2		0.001
Eucalyptus regnans	44	49	3	5			
Eucalyptus smithii					100		
Euchiton collinus			100				
Eucryphia moorei					100		
Eupomatia laurina					100		
Eustrephus latifolius		6			94		0.0001

Fieldia australis	14	27	6	1	40	11	0.0219
Gahnia clarkei		5	2		93		0.0118
Gahnia melanocarpa					88	12	0.0001
Gahnia sieberiana					100		
Geitonoplesium cymosum					100		
Gnaphalium spp.			100				
Goodia lotifolia					100		
Goodenia ovata			100				
Grammitis billardierei	11	30	31	16	9	3	
**Hedera helix*	100						
Hedycarya angustifolia	20	7	48		18	7	0.0043
Histiopteris incisa	18	11	13	33	18	6	
**Holcus lanatus*			100				
**Huperzia varia*			100				
Hydrocotyle hirta	13	16	54		16		
Hymenophyllum australe	8	20	65	4	2		0.0003
Hymenophyllum cupressiforme	8	9	31	16	27	9	
Hymenophyllum flabellatum	20	20	42	18			0.0598
Hymenophyllum rarum	8	17	42	34			
**Hypericum androsaemum*			44		56		
Hypolepis muelleri					100		
Hypolepis rugosula	18		18	51	13		
**Ilex aquifolium*	100						
Isolepis fluitans	100						
Isolepis inundata	5	12	36	24	24		
Juncus pauciflorus			100				
Lastreopsis acuminata	5	10	23	1	40	21	0.049
Lastreopsis hispida			100				
Lepidosperma elatius	9	42	1	47			
Lepidosperma laterale		67			33		
Lobelia pedunculata s.l.			100				
Lomatia fraseri	9	53	14	24			
**Lonicera japonica*	100						
Macroglena caudata		17			83		
Marsdenia rostrata	1				95	4	0.0001
Microsorum pustulatum subsp. *pustulatum*	7	67	15	5	5		0.0001
Microsorum scandens	1	31			54	13	0.0016
Morinda jasminoides					87	13	0.0005
Notelaea ligustrina	9	11	59	22			
Notelaea venosa		11			89		0.0005
Nothofagus cunninghamii	4	11	85	1			0.0001
Olearia argophylla	15	18	8	30	26	3	
Olearia lirata	13	16	14		56		
Oplismenus hirtellus					100		
Pandorea pandorana	5	44		5	31	15	
Parsonsia brownii	8	26	8	6	39	13	
Pellaea falcata s.l.		53	2		44		0.0544
Pittosporum bicolor	11	23	30	33		3	
Pittosporum undulatum		1			99		0.0001
Plantago debilis					100		
Poa ensiformis					100		
Poa labillardierei var. *labillardierei*			100				
Polyscias murrayi					100		
Polystichum proliferum	19	6	13	43	15	5	
Pomaderris apetala				100			0.0001
Pomaderris aspera	28	24		1	42	4	0.0424
Prostanthera lasianthos var. *lasianthos*	12		15		73		0.0495
Prostanthera melissifolia					100		
Pteridium esculentum	10	55			35		0.0346
Pteris tremula					100		
Pteris umbrosa					100		0.0001
Pyrrosia rupestris					88	12	0.0003
Rapanea howittiana		4	1		88	7	0.0211
**Rubus fruticosus* agg.	31		18		51		
Rubus moluccanus var. *trilobus*	3				63	34	0.0026
Rubus parvifolius					100		
Rubus rosifolius var. *rosifolius*	3				70	26	0.0122
Rumohra adiantiformis	16	9	28	19	13	15	
Sambucus gaudichaudiana	28	32	11		29		
Sarcopetalum harveyanum					89	11	0.0002
Schoenus maschalinus					100		

Senecio minimus			11		89		
Senecio spp.	77		23				
Smilax australis	1	4			93	3	0.0001
Stellaria flaccida	43	6	9		22	20	
Sticherus lobatus		57	1		41		0.0157
Sticherus tener s.l.		29	71				
Tasmannia lanceolata	8		7	66	19		0.0202
Tetrarrhena juncea	23	11	3	11	52		0.032
Tmesipteris obliqua	6	13	6	6	64	5	
Tmesipteris ovata					100		0.0113
Tmesipteris parva	3	22			63	12	0.0226
Todea barbara		11	5	79	5		
**Tradescantia fluminensis*	100						
Tristaniopsis laurina					100		
Tylophora barbata					100		0.0003
Uncinia nemoralis			100				
Uncinia tenella	6	29	43	10	12		
Urtica incisa	12	17	28	11	31		
Viola hederacea	4	14	4	5	58	15	0.0078
Viola odorata	100						
**Watsonia meriana*	100						
Zieria arborescens subsp. *arborescens*		80	1	19			0.0064

Appendix 3 The threat status of *Cyathea cunninghamii* and *Cyathea* x *marcescens* according to National and various State Legislations

	Cyathea cunninghamii	***Cyathea* x *marcescens***
National		
Rare or Threatened Australian Plants (Briggs and Leigh 1996)	rare	not listed
ANZECC Threatened Australian Flora list (1999)	rare	not listed
Environment Protection and Biodiversity Conservation Act (1999)	not listed	not listed
New South Wales		
Threatened Species Conservation Act (1995)	not listed	outside distribution
Victoria		
Department of Sustainability and Environment (2005) Advisory List of Rare or Threatened Plants in Victoria (2005)	vulnerable	threatened
Flora and Fauna Guarantee Act 1988 Section 10 (2012)	vulnerable	outside criteria (sterile hybrid)
Tasmania		
Flora Advisory Committee (1994)	rare	endangered
Threatened Species Protection Act (1995)	not listed	endangered
Queensland		
Nature Conservation Act (1992)	near threatened	outside distribution

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Revisiting Tony Price's (1979) account of the native vegetation of Duck River and Rookwood Cemetery, western Sydney

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***Abstract*:** The Duck River Reserve and Rookwood Cemetery in the highly urbanised Auburn district of western Sydney hold small but botanically valuable stands of remnant native vegetation. In the late 1970s, local resident G.A. (Tony) Price, recognised the value of these remnants, both for the species they held and the clues they could give us to the past, and spent three years surveying and collecting plants at these sites. Price recorded the species present and their abundance, and described the habitats in which they were found. He observed the ecology of plant interactions, moisture, shading and fire response, interpolating them into a picture of the landscape and vegetation of the district prior to European settlement. At a time when field botany was inaccessible to many, and the focus of conservation was largely on the broader scale, Price's local scale work at these sites was unusual and important. Though never formally published, Price's 1979 account '*The Vegetation of Duck River and Rookwood Cemetery, Auburn*' has been cited in all subsequent work of consequence for the area. This paper presents and reviews Price's work and discusses his observations in relation to the current vegetation of these areas. Tony Price's contributions also highlight the value and role that ordinary citizens can play alongside professional botanists and plant ecologists in long term data collection, considered observation and environmental management. A copy of Price's original unpublished account has been included as an appendix to this paper.

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Introduction

The Auburn district is approximately 18 km west of Sydney Harbour, on the eastern margin of the Cumberland Plain, that makes up the landscape of most of western Sydney. Agriculture and urbanisation in the 200 years since European arrival has resulted in the loss of an estimated 99% of the original native vegetation cover in the Auburn Local Government Area (NPWS 1997). Small remnants of native vegetation still survive in the perimeters of council parks and along railway corridors and creek banks. The largest stands are in Rookwood Cemetery and in the Duck River Reserve at South Granville where small, but botanically valuable, remnants of four communities listed as Critically Endangered Ecological Communities under the NSW *Threatened Species Conservation Act, 1995* (TSC Act) occur. These are Cooks River/ Castlereagh ironbark forest (CRCIF), Cumberland Plain woodland (CPW), Shale Gravel Transition forest, and Sydney Coastal River Flat Forest – Alluvial Woodland, lining the riverbank of the Duck River Reserve (species assemblages are described in the Final Determinations of the NSW Scientific Committee). The Duck River Reserve and Rookwood Cemetery also encompass important populations of two species listed as Vulnerable, (*Acacia pubescens* and *Epacris purpurascens* var. *purpurascens*) and two populations listed as Endangered (*Pomaderris prunifolia* and *Wahlenbergia multicaulis*) (Greening Australia 1990, Rookwood Plan of Management 1995). The two areas hold

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more than 20 floral taxa considered regionally significant because they are either rare or inadequately conserved in Western Sydney e.g., *Asterolasia correifolia, Macrozamia spiralis* and *Eucalyptus viminalis* at Duck River and *Dillwynia parvifolia*, *Juncus procerus* and *Gonocarpus longifolius* at Rookwood (Greening Australia 1990, NPWS 1997, James *et al*. 1999). The sites also provide habitat for listed vulnerable animal species such as the grey-headed flying fox, eastern bentwing bat, Cumberland land snail, regent honeyeater and green and golden bell frog. In addition, several bird species rare to the Sydney district, such as the zebra finch, yellow-rumped thornbill, diamond fire-tail finch and double-barred finch; species that feed exclusively on grass seeds but require shrubby cover for nesting have been recorded (EDAW 1996, Smith & Smith 1999, Applied Ecology 2011).

In the late 1970s, local Auburn resident G A (Tony) Price, recognised the value of these remnants both for the species they held and the clues they could give to past vegetation patterns, spent three years surveying and collecting plants in the area. He compiled an extensive list of the existing plant species, recorded ecological observations, and interpolated them into a picture of the landscape and vegetation of the district at the time of European settlement, in his unpublished account *The Vegetation of Duck River and Rookwood Cemetery, Auburn*. An electronic copy of Price's original account is included as Appendix 2 to this paper.

Greville Anthony (Tony) Price (1934–2010) grew up in Auburn and was a high school English/ History teacher and an avid collector of books. He gained his Master of Arts with 1st Class Honours in History from the University of New England in 1964. He was also a student in the (then) School of Biological Sciences at Macquarie University in the 1980s. Aside from short teaching posts in Canberra and Armidale, Tony Price lived in the house on Park Rd, Berala that he owned and his parents owned before him. He died in April 2010 at age 75 (Kathleen Mealing, Laurence Gordon, Margot Wood pers. comm.).

Tony Price was widely consulted for his botanical knowledge, and his ecological work and opinions provided baselines for research, as well as environmental management by councils, catchment authorities, community groups and others, both locally and within the wider district. He was a founding member of the Friends of Duck River Reserve whose activities included: petitioning for interpretative signage; instigating fencing of the area to protect it from minibike riders and overflow parking at the Melita Soccer Stadium; gaining funding for the removal of old car bodies from the reserve; ensuring the retention of trees along the riverbanks; propagating local species and undertaking bush regeneration work.

Tony Price left a small bequest to Macquarie University to support future plant ecology research. This paper was supported by that bequest.

Methods

Duck River and Rookwood site descriptions

The Duck River Reserve covers 16 ha of Parramatta City Council Reserve 20 km west of Sydney's Central Business District on the western banks of Duck River, between Wellington and Everley Roads in South Granville (33°52"04'S, 151°00"48'E). Rookwood Cemetery lies 4km east between Lidcombe and Strathfield (33° 52"25'S, 151° 03"58'E) covering 286 ha of Crown land under the control of the NSW Department of Lands, the majority intensively used as a cemetery. Conservation areas within Rookwood today total approximately 18 ha (DEM 2006).

Topography of the Auburn district is level to slightly undulating. Broad valleys and an alluvial floodplain drain the area that is 20 – 50 m above sea level, with gradients of less than three percent (Branagan *et al.* 1979, Parramatta River 9130–3N and Botany Bay 9130–3S 1: 25 000 topographic maps). Duck River flows into the Parramatta River, draining the suburbs of Auburn, Berala and Birrong to the east, Sefton, Chester Hill, Granville and Clyde to the west and the northern part of Yagoona to the south. Eighty percent of river discharge is generated in wet weather flowing from impermeable urban surfaces and stormwater and carrying high nutrient loads and debris (EDAW 1996). The major drainage lines within Rookwood Cemetery are brick-lined canals (Price 1979).

The geology of the district comprises Ashfield and Bringelly shales of the Wianamatta Group, with a small sandstone outcrop at Duck River (Price 1979). The soils are yellow podsols, comprising silt and clay-sized alluvial materials, with additional areas of disturbed soils present (EDAW 1996). The area is classified as belonging to the Birrong Soil Landscape, characterised by soils that show seasonal waterlogging, low water permeability, low fertility, low water availability, low wet strength with hardsetting surfaces, and subsoils that are often saline (Chapman & Murphy 1989). Soil depth varies but is typically 60 mm to clay and 1.8 m to shale (Glenn Piggott, pers. comm.).

The climate has mild, wet winters and warm, wet summers. Monthly average temperatures show summer maxima of 28.1° C in January, 17.2° C in July; and winter minima of 5.1° C in July, 18° C in January. Annual average rainfall is 983 mm (data from the Bureau of Meteorology, nearest rainfall records from Rookwood (Hawthorne Ave), nearest temperature records from Bankstown Airport).

History

Prior to European occupation, the Auburn district was occupied by the 'woods tribes' or Darug people. The Darug did not depend on fish and shellfish as the coastal indigenous peoples did; instead small animals and the tubers of native vines, lilies and orchids growing in the area comprised an important part of their diet (Granville Historical Society 1992, Kohen 1993).

European settlers referred to the district around Auburn as 'Liberty Plains' with land granted to free settlers from 1793 (Auburn Municipal Council 1982). From the early 1800s, timber was extracted from the area – ironbark and turpentine trees for use in wharves and bridges; stringybarks for railway sleepers and roofing; and other local tree species for general firewood. Later, wattlebark was extracted for use in tanneries that operated along Duck River (Granville Historical Society 1992). As timber availability decreased, orchards and vineyards were tried but were unsuccessful, and the land was subsequently subdivided and sold for dairies, poultry farms and market gardens (Auburn Municipal Council 1982, Granville Historical Society 1992).

The Duck River Reserve is all that has survived from the original 600 acres granted to James Chisholm, a sergeant of the NSW Corps in 1823. It was grazed and sold on to a timber merchant in 1882 and then investors in 1885, before being purchased by Parramatta City Council in 1946 (Price 1979; Greening Australia 1990). Since this time, Parramatta City Council has maintained it as a public open space, while developing adjoining land as rubbish tips and a 'night soil' area, which more recently have become sporting fields and a golf course (EDAW 1996). By the end of the 1800s, there was much heavy industry operating along Duck River including Hudson's, Clyde Engineering and later the Commonwealth Engineering or Comeng site. Factory sites included flour mills, iron works, tool makers and several tanneries from 1877 (Granville Historical Society 1992).

In 1860 the *Government Gazette* newspaper carried an advertisement for '100 acres of land which may be suitable for a General Cemetery', setting out general requirements such as soil 'of considerable depth', 'drainage to an area whence water supply is not obtained for domestic purposes' and close proximity to 'the Great Southern Railway between Sydney and Parramatta' (Sigrist 1989). The government surveyor who subsequently visited the Auburn district reported that 'Cohen's Hyde Park Estate at Liberty Plains was covered with dense ti-tree and wattle scrub and wooded with mahogany, stringy bark and hollybutt, though the best timber had already been cut out' (Rookwood Plan of Management 1993). The land was purchased in lots in 1861 and 1864, and the first burial occurred at Rookwood in 1867. More land was purchased as burials increased in the decades that followed. Rookwood Necropolis is now the largest cemetery in the southern hemisphere (Rookwood Plan of Management 1993).

Material and data sources

Tony Price conducted his fieldwork in 1976, 1977 and 1978 and completed his written account in 1979. He states that he studied the Duck River site most intensively. He collected voucher specimens, utilised the limited number of published field guides that were available at that time and took specimens to the identification counter at the Royal Botanic Gardens in Sydney for assistance. He recorded abundance estimates on all species, coding them as common (X), occasional (O) or rare (R) but did not record a decision rule as to how species were assigned into these abundance classes. He carefully recorded the habitat/s in which each species was found, dividing these into his eight 'micro-environments'*: 1. low woodland, Duck River; 2. ti-tree and eucalypt scrub; 3. grasslands; 4. exposed soils and subsoils; 5. drainage lines, edges of permanent sheets of water, creeks etc.; 6. permanent and transient sheets of water; 7. graves, Rookwood cemetery; and 8. dumped soil, edges of roads and tracks.* Price was also interested in the ecological processes that were occurring in the vegetation and made notes on the apparent regeneration and establishment requirements of species: their light and shade tolerances and responses to waterlogging, drought, fire and soil disturbance.

Based largely on his surveys of the remnant native vegetation at Duck River and Rookwood Cemetery, Price reconstructed a picture of pre-European vegetation for the Auburn district. He also drew from his observations of the 'scattered, veteran eucalypts' of the State hospital grounds at Lidcombe, the Carnarvon Golf Course at Berala, and various parks and yards immediately east and west of these sites. He incorporated his knowledge of local land use and fire history and compared his conclusions on the pre-European vegetation with those postulated earlier by Pidgeon (1941) and Kartzoff (1969).

Analysis

An interpretation of Tony Price's 1979 account is presented, drawing from both his species list and written comments for details of vegetation structure, floristic and growth form assemblage, species richness and weed invasion at the sites. An examination of Price's species records was made, tallying richness and growth form and extracting records of species restricted within each of his eight microenvironments. Comparisons are made between the sites, to later studies at these and other western Sydney sites, and to the vegetation of these sites today. Sorensen's index was calculated as a similarity index between the two sites: Similarity = 2a/(2a +

Table 1: Species and family richness (raw numbers with percentages in brackets)

	Total	Rookwood	Duck River	Unique to Rookwood	Unique to Duck River	Occurring both sites
Native species	311 (53%)	212 (53%)	254 (54%)	58	99	154 (50%)
Exotic species	273 (47%)	186 (47%)	213 (46%)	59	87	127 (47%)
All species	584	398 (68%)	467 (80%)	117 (20%)	186 (32%)	281 (48%)
Families	110	89	99	11	21	78

b +c) where a = the number of species present at both sites, b = the number of species present only at Rookwood, and c = the number of species present only at Duck River.

Price's species list (reproduced in Appendix 1) has been updated with plants listed alphabetically by current species name, within current family, under subheadings of growth form (derived from PlantNet and APNI websites). Species that Price recorded twice under two different names and are now considered the same species (taxonomic synonyms) have been listed only once (3 species) under their currently accepted name. Species missing both site and habitat codes (4 species) have been excluded. Species with missing or indecipherable site codes (2 species) or habitat recordings (35 species) have been included but location data left blank. The 35 taxa without habitat codes could not be used in habitat analyses. A number of other minor amendments, such as correcting spelling errors, or the erroneous coding of native species as weeds (or vice versa) were made.

Results

Price recorded a total of 584 species across the two sites: 311 native and 273 exotic (Table 1). The most species rich families were the Poaceae (88 species), Myrtaceae (61 species), Asteraceae (49), Fabaceae subfamily Faboideae (46) and subfamily Mimosoideae (16), and Iridaceae (16). In terms of both native and exotic species Duck River was floristically more diverse than Rookwood. A higher number of plant families were also found at Duck River.

The proportions of native and exotic species are remarkably consistent at the two sites (53 –54% native, 46–47% exotic). 50% of the native species and 47% of exotics occurred at both sites. Sorensen's similarity index for the two sites was 0.64 for all species, 0.66 for native flora and 0.63 for exotic flora.

The proportions of the nine growth forms were also remarkably similar at the two sites (Table 2), as was the ranking of the growth forms based on the numbers of species within each (Figure 1). Herbs were the most numerous growth form, comprising 37–39% of species. Graminoids (grasses, sedges and rushes) were the next most numerous, comprising ~21% of species. Shrubs followed at 16–19%, trees 12–15%, subshrubs and climbers, each made up 4–5% of species recorded, with ferns, succulents and aquatics in lesser numbers and each comprising <1% of growth forms recorded. Duck River had more native and exotic herb, graminoid, shrub and climber growth forms. Rookwood had slightly higher numbers of native and exotic tree species overall, while subshrubs, aquatics and succulents occurred in similar numbers at the two sites (Table 2).

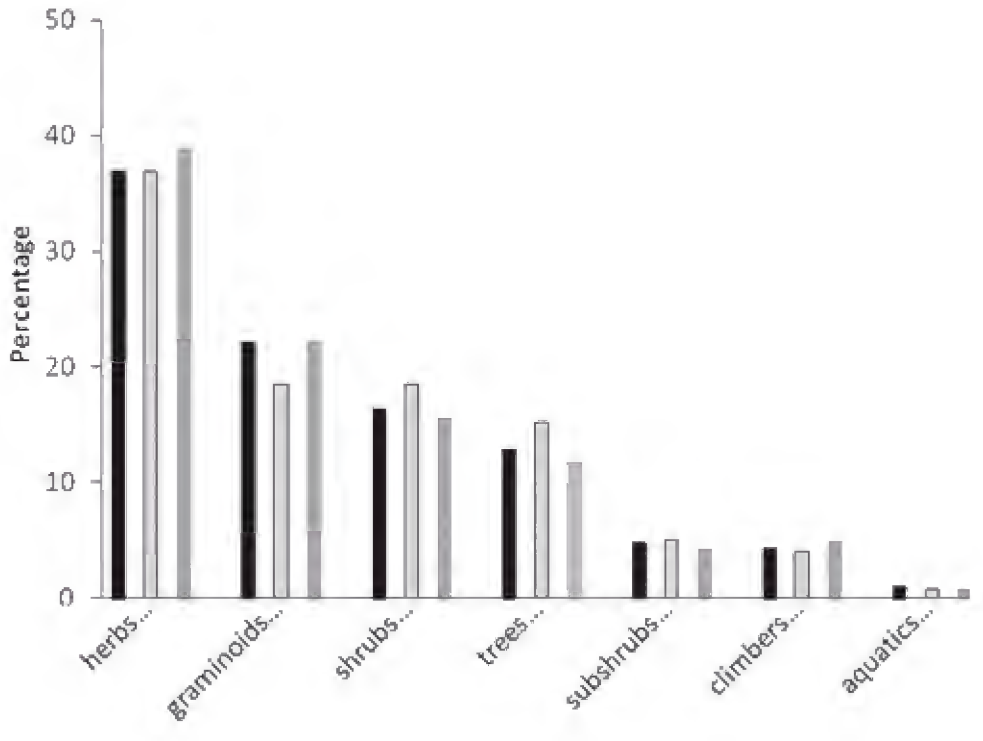
Of the 8 microenvironments, ti-tree and eucalypt scrub was the most species-rich (230 species) and a high percentage of those species (78%) were natives (Figure 2, Table 3). Grasslands had the second highest number of species recorded (n=209) but a smaller percentage were native (61%). The drainage lines, creeks and edges of water also held high numbers of species, (n=195) but a higher percentage of those were exotic (58%). A large number of species were recorded

Table 2: Total, native and exotic species by growth form present at the Rookwood and Duck River sites. Species numbers shown are total at each site, unique to each site and occurring at both sites

	Total			Rookwood			Duck River			Unique to Rookwood			Unique to Duck River			Occurring both sites		
	Natives	Exotics	Tot	Natives	Exotics	Tot	Natives	Exotics	Tot	Natives	Exotics	Tot	Natives	Exotics	Tot	Natives	Exotics	Tot
Herbs	83	132	215	50	94	144	71	111	182	12	21	33	32	37	69	39	74	113
Graminoids	73	56	129	44	29	73	58	46	104	15	10	25	29	27	56	29	19	48
Shrubs	67	30	97	50	24	74	53	20	73	14	10	24	17	6	23	36	14	50
Trees	43	32	75	36	24	60	35	20	55	8	12	20	7	8	15	28	12	40
Sub-shrubs	25	4	29	18	3	21	17	3	20	8	1	9	7	1	8	10	2	12
Climbers	15	10	25	10	6	16	14	9	23	1	1	2	5	4	9	9	5	14
Aquatics	1	5	6	1	2	3	1	3	4	0	2	2	0	3	3	1	0	1
Ferns	4	1	5	2	1	3	4	0	4	0	1	1	2	0	2	2	0	2
Succulents	0	3	3	0	2	2	0	2	2	0	1	1	0	1	1	0	1	1
Total	311	273	584	211	185	396	253	214	467	58	59	117	99	87	186	154	127	281

Table 3: Number of plant species in each of nine growth forms found in Price's eight micro-environments.

		trees	**shrubs**	**subshrubs**	**graminoids**	**herbs**	**climbers**	**ferns**	**succulents**	**aquatics**	**Total**
Low Woodland, Duck River	Natives	21	32	7	14	22	10	2	0	0	107 (80%)
	Exotics	1	7	1	2	13	3	0	0	0	27 (20%)
	total	22	39	8	16	35	13	2	0	0	135
Ti-tree and eucalypt scrub	Natives	26	50	15	31	42	12	1	0	0	179 (78%)
	Exotics	5	9	1	8	28	2	0	0	0	51 (22%)
	total	31	59	16	39	70	14	1	0	0	230
Grassland	Natives	11	18	11	45	37	5	1	0	0	128 (61%)
	Exotics	2	5	0	28	45	1	0	0	0	81 (39%)
	total	13	23	11	73	82	6	1	0	0	209
Exposed soils and subsoils	Natives	7	14	3	10	4	3	0	0	0	41 (71%)
	Exotics	0	3	0	8	5	0	0	1	0	17 (29%)
	total	7	17	3	18	9	3	0	1	0	58
Drainage lines, creeks and edges of water	Natives	7	20	2	26	15	2	2	0	0	82 (42%)
	Exotics	14	10	1	27	58	6	2	1	2	113 (58%)
	total	21	30	3	53	73	8	4	1	2	195
Permanent and transient sheets of water	Natives	0	0	0	4	2	0	0	0	1	7 (44%)
	Exotics	0	0	0	5	1	0	0	0	3	9 (56%)
	total	0	0	0	9	3	0	0	0	4	16
Graves, Rookwood	Natives	11	6	1	3	4	0	1	0	0	26 (33%)
	Exotics	14	13	2	5	17	1	0	1	0	53 (67%)
	total	25	19	3	8	21	1	1	1	0	79
Dumped soil, edges of roads, tracks	Natives	9	5	2	9	10	1	0	0	0	35 (26%)
	Exotics	3	6	3	26	60	3	0	1	0	102 (74%)
	total	12	11	5	35	70	3	0	1	0	137



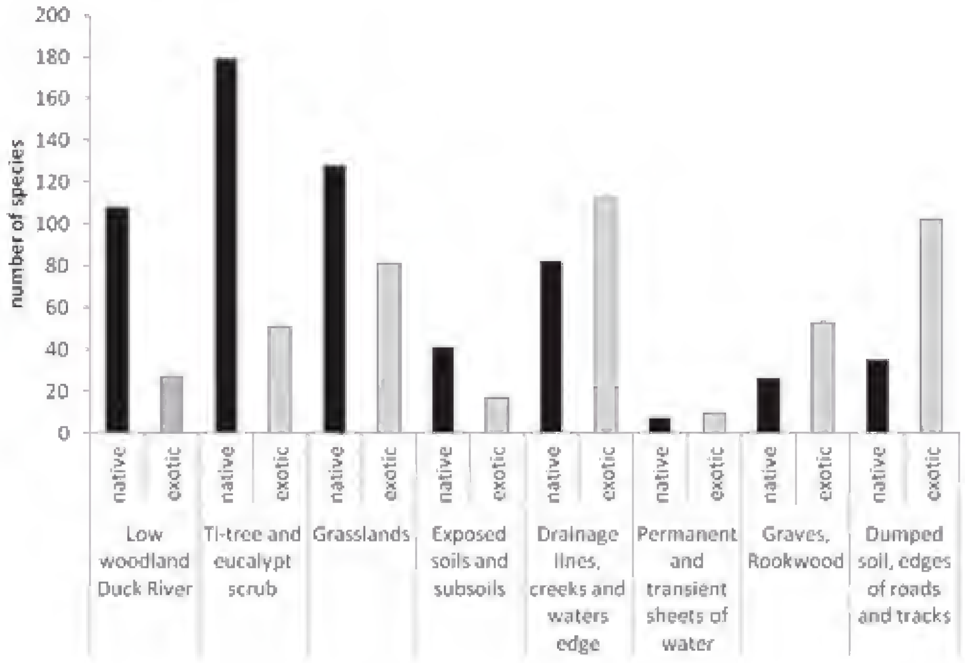


Fig. 1. Proportions of the 9 growth forms derived from Price (1979) as recorded at both sites ■ (total), at Rookwood □ and Duck River ▨ .

Fig. 2. The number of native and exotic species recorded by Price (1979) in each of his eight 'microenvironments'.

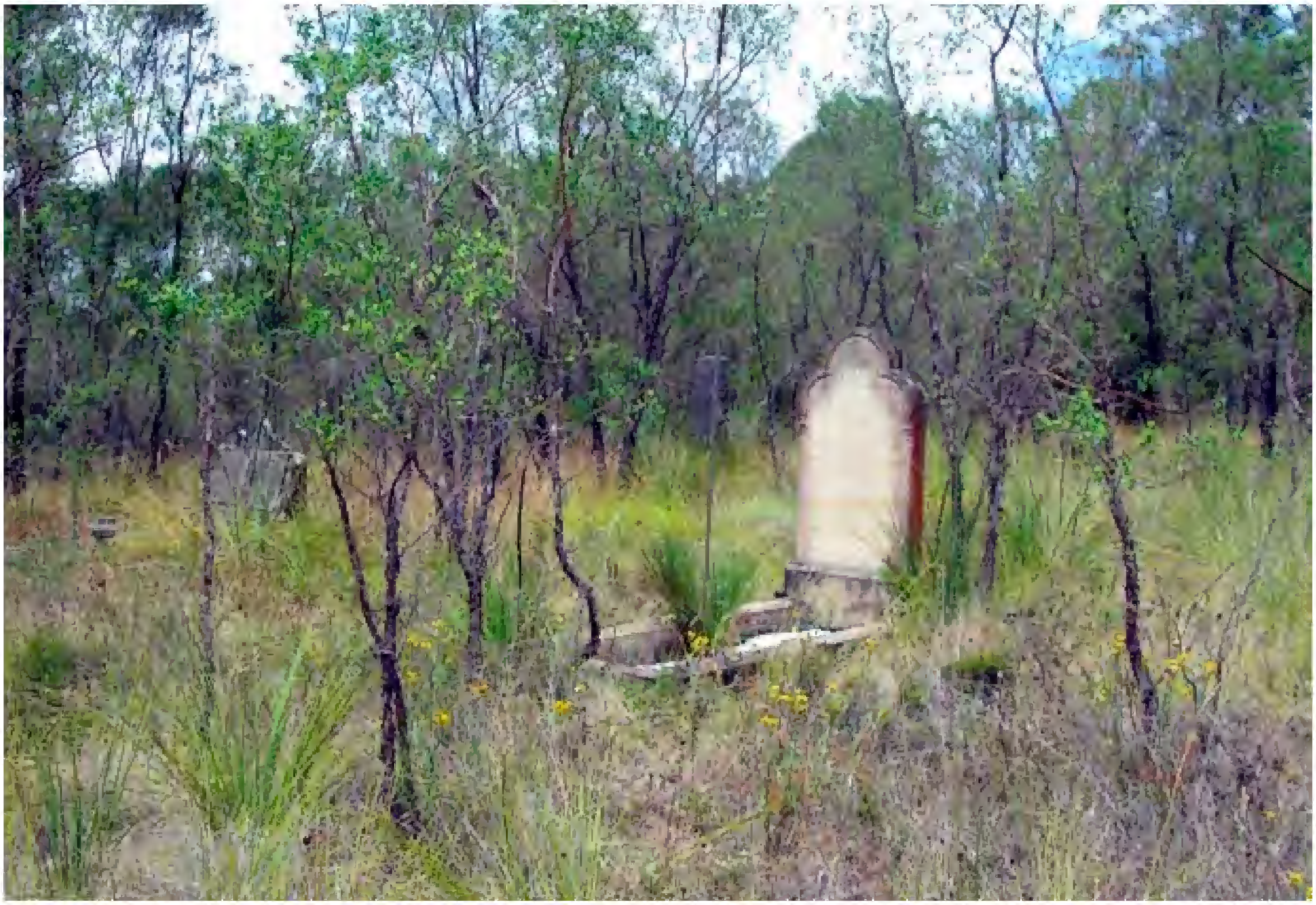


Fig. 3. Rookwood regeneration over graves: Some older sections of the cemetery are being managed to allow native plant regeneration with species present in this area including *Dillwynia parvifolia*, *Daviesia ulicifolia*, *Xanthorrhoea resinosa*, *Macrozamia spiralis*, *Coronidium scorpioides*, *Stylidium graminifolium*, *Chrysocephalum apiculatum*, *Lissanthe strigosa*, *Angophora bakeri*, *Themeda australis*, *Patersonia longifolia*, *Pultenaea villosa*, *Hibbertia aspera*, *Leptospermum trinervium*, *Bursaria spinosa*, *Leucopogon juniperinus*, *Lomandra gracilis*, *Lepidosperma laterale*, *Hakea sericea* seen here growing amongst the headstones.

Table 4a: Numbers of native and exotic species recorded in only 1 of the 8 micro-environments recognised by Price.

		trees	**shrubs**	**subshrubs**	**graminoids**	**herbs**	**climbers**	**ferns**	**succulents**	**aquatics**	**Totals**
Low Woodland, Duck River	Natives	1		2	1	7	1				12
	Exotics					2	1				3
Ti-tree and eucalypt scrub	Natives	2	13	4	7	9	3				38
	Exotics	1				2					3
Grassland	Natives	1	1	3	15	9					29
	Exotics		1		5	7					13
Exposed soils and subsoils	Natives		2	1		3					6
	Exotics		1		1	1			1		4
Drainage lines, creeks and edges of water	Natives	2	9	2	10	9	1	2			35
	Exotics	3	1		10	24	3			1	42
Permanent and transient sheets of water	Natives				2	1				1	4
	Exotics				4					3	7
Graves, Rookwood	Natives		1			1					2
	Exotics	8	4	1	2	5			1		21
Dumped soil, edges of roads, tracks	Natives				1	4					5
	Exotics		2	1	6	24					33
Totals	Natives	6	26	12	36	43	5	2	0	1	131
	Exotics	12	9	2	28	65	4	0	2	4	126
	Combined	18	35	14	64	108	9	2	2	5	257

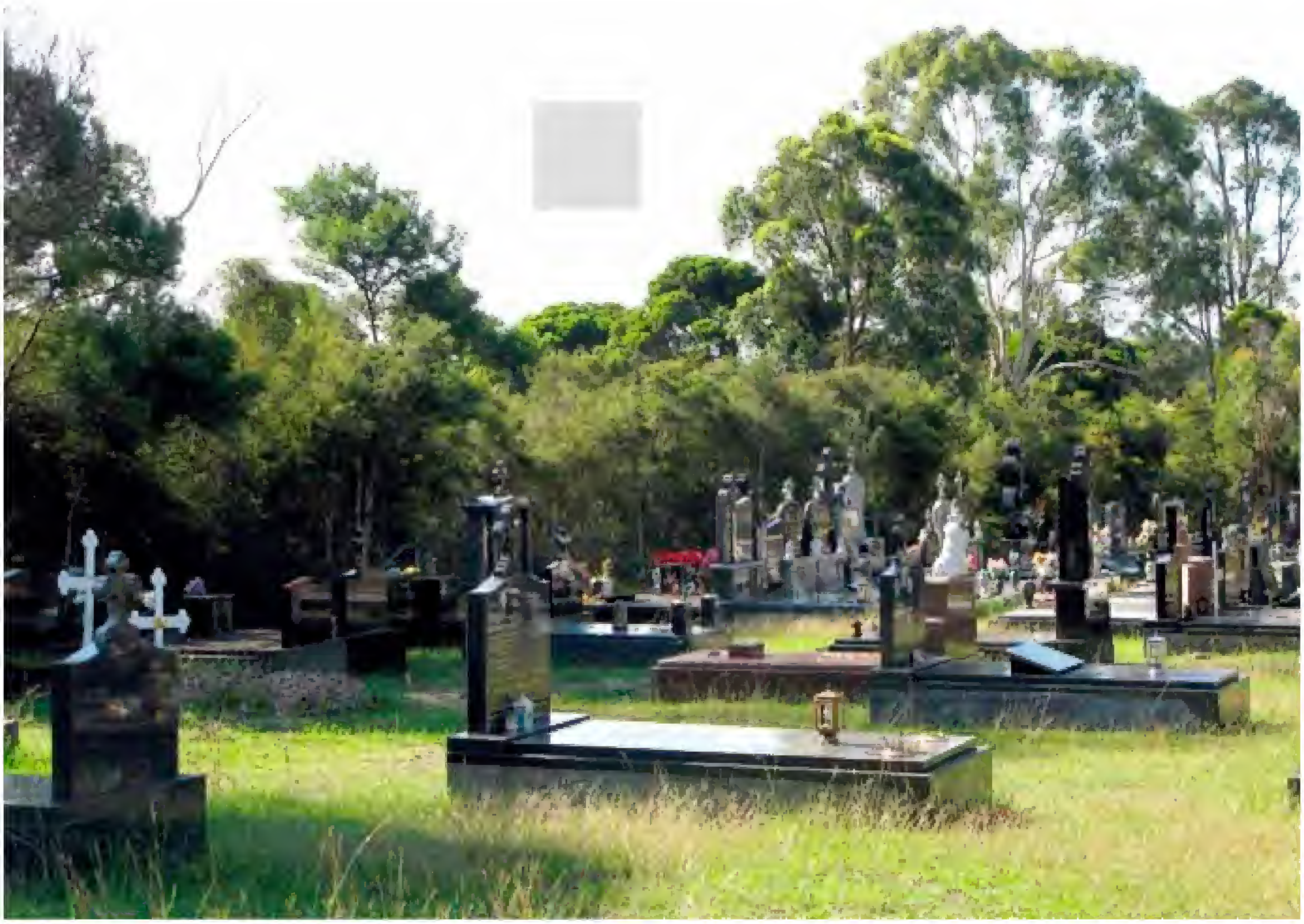


Fig. 4. Recent Rookwood graves in the foreground to one of the areas Tony Price termed 'ti-tree and eucalypt scrub' now a designated conservation area within the cemetery. Scattered *Eucalyptus resinifera*, *Eucalyptus tereticornis*, *Eucalyptus sclerophylla*, *Angophora bakeri* and *Angophora floribunda* overtop *Melaleuca nodosa* and *Melaleuca decora* with its striking mistletoe *Amyema gaudichaudii*. More unusual species in this area include *Rhytidosporum procumbens*, *Hibbertia pedunculata*, *Dillwynia tenuifolia*, *Melaleuca erubescens*, *Bossiaea prostrata*, *Pultenaea retusa*, *Xanthorrhoea resinosa*, *Banksia spinulosa* and *Banksia oblongifolia*.

from dumped soil, edges of roads and tracks (n=137), with many of those being exotic (74%). The low woodland at Duck River held a similar number of species (n=134), but conversely showed the highest percentage of native species (80%).

A total of 257 species (131 native and 126 exotic) were recorded in only one of the eight micro-environments recognised by Price (Table 4a). From an overall total of 584 species, this represents 44% of all species, being generally more restricted or rarer in occurrence. Of note are the 38 native species, of which 13 are shrubs, recorded only in the ti-tree and eucalypt scrub; the 29 natives (15 graminoids) recorded only in the grasslands; the 42 exotic species restricted to the drainage lines (24 of them exotic herbs) and 33 exotic species (with a further 24 exotic herbs) restricted to the disturbed soil environments, as well as an interesting suite of 21 exotic species restricted to graves (Table 4b).

In his 1979 account Price made numerous observations on individual species, their regeneration and establishment requirements, light and shade tolerances and responses to waterlogging, drought, fire and soil disturbance. He also recorded flowering and fruiting times for the dominant eucalypts. Many of these observations have been subsequently incorporated into the 'Ecology of Sydney Plant Species' series by Benson and McDougall in *Cunninghamia* (1993–2005). Readers can go to this source for more comprehensive information on the ecology of individual plant species.

Discussion

Tony Price's account raises a wide range of issues that are relevant to the conservation and management of remnant bushland in an urban context today. In light of current plant ecological understanding and the vegetation at the sites today I review Price's work below under six headings: a) his picture of the vegetation of the Auburn district as it was prior to European settlement; b) his insights into the ongoing vegetation dynamics occurring at these sites in relation particularly to fire, moisture and light; c) his work as it informs

Table 4b: Species recorded in only 1 of the 8 microenvironments, arranged by growth form. Exotics are indicated by an asterisk.

Species restricted to low woodland, Duck River:

Trees: *Glochidion ferdinandi*

Subshrubs: *Boronia polygalifolia, Pomax umbellata*

Graminoids: *Juncus homalocaulis*

Herbs: *Brunoniella pumilio, Brunoniella australis, Einadia polygonoides, Brachyscome linearifolia, Cardamine lilacina, Scaevola albida, Lagenophora stipitata, *Aptenia cordifolia, *Polycarpon tetraphyllum*

Climbers: *Tylophora barbata, *Asparagus plumosus*

Species restricted to ti-tree and eucalypt scrub:

Trees: *Allocasuarina littoralis, Eucalyptus sideroxylon,*Morus nigra*

Shrubs: *Isopogon anemonifolius, Persoonia laurina, Pomaderris prunifolia, Exocarpos strictus, Banksia spinulosa* var. *spinulosa, Epacris purpurascens* var. *purpurascens, Melaleuca erubescens, Podolobium ilicifolium, Monotoca scoparia, Acacia stricta, Acacia suaveolens, Notolaea ovata, Banksia oblongifolia*

Subshrubs: *Hibbertia diffusa, Gompholobium minus, Opercularia aspera, Micrantheum ericoides*

Graminoids: *Gahnia melanocarpa, Digitaria parviflora, Dianella revoluta, Lomandra multiflora* subsp. *multiflora, Lomandra longifolia, Austrodanthonia racemosa* var. *racemosa, Paspalidium aversum*

Herbs: *Einadia nutans* subsp. *linifolia, Senecio quadridentatus, Senecio linearifolius, Solenogyne bellioides, Vittadinia dissecta, Wahlenbergia stricta, Goodenia heterophylla, Orthoceras strictum, Pterostylis nutans, *Chenopodium album, *Tropaeolum majus,*

Climbers: *Billardiera scandens* var. *scandens, Cassytha glabella, Cassytha pubescens*

Species restricted to grasslands:

Trees: *Melaleuca quinquenervia*

Shrubs: *Melaleuca armillaris, *Nerium oleander*

Subshrubs: *Bossiaea buxifolia, Gompholobium glabratum, Gonocarpus longifolius*

Graminoids: *Carex inversa, Eragrostis leptostachya, Sporobolus elongatus, Austrodanthonia setacea, Lomandra cylindrica, Lomandra fluviatilis, Lomandra gracilis, Dichelachne rara, Austrostipa mollis, Aristida ramosa, Eriochloa pseudoacrotricha, Panicum simile, Sorghum leiocladum, Juncus procerus, Juncus sarophorus, *Dactylis glomerata, *Phalaris minor, *Poa pratensis, *Briza subaristata, *Chloris gayana*

Herbs: *Calotis lappulacea, Senecio pinnatifolius* var. *pinnatifolius, Linum marginale, Caesia parviflora, Caesia parviflora* var. *vittata, Zornia dyctiocarpa, Goodenia bellidifolia, Plantago varia, Hypoxis hygrometrica, ,*Cerastium glomeratum *Lotus subbiflorus, *Richardia stellaris, *Misopates orontium, *Sparaxis spp., *Silene gallica* var. *gallica, *Romulea longifolia*

Species restricted to exposed soils and subsoils:

Shrubs: *Acacia longissima, Kunzea ambigua, *Lycium ferocissimum*

Subshrubs: *Astroloma humifusum*

Graminoids: **Ehrharta longiflora*

Herbs: *Dysphania littoralis, Vittadinia muelleri, Chamaesyce drummondii, *Hypochaeris microcephala*

Succulents: **Aloe* spp.

Species restricted to drainage lines, creeks:

Trees: *Melaleuca linariifolia, Casuarina glauca, *Salix babylonica, *Prunus domestica, *Prunus persica,*

Shrubs: *Leucopogon lanceolatus var. lanceolatus, Leptospermum polygalifolium, Melaleuca ericifolia, Hovea longifolia, Goodenia ovata, Persoonia linearis, Viminaria juncea, Pomaderris lanigera, Asterolasia correifolia, *Ricinus communis*

Subshrubs: *Mirbelia rubiifolia, Opercularia varia*

Graminoids: *Juncus subsecundus, Juncus continuus, Schoenus apogon, Crinum pedunculatum, Cyperus mirus, Amphibromus neesii, Phragmites australis, Joycea pallida, Arundinella nepalensis, Urochloa foliosa, *Stenotaphrum secundatum, *Phormium tenax, *Bromus molliformis, *Bromus rubens, *Cortaderia selloana, *Eragrostis curvula, *Holcus lanatus, *Axonopus fissifolius, *Pennisetum glaucum, *Setaria palmifolia,*

Herbs: *Centrolepis strigosa, Centipeda minima, Epilobium billardierianum subsp. cinereum, Einadia trigonos, Isotoma fluviatilis, Goodenia paniculata, Persicaria lapathifolia, Persicaria decipiens, Solanum americanum, *Zantedeschia aethiopica, *Spergularia rubra, *Stellaria media, *Bidens subalterans, *Apium graveolens, *Hydrocotyle bonariensis, *Leucojum aestivum, *Canna indica, *Canna spp., *Brassica fruticulosa, *Brassica juncea, *Brassica rapa subsp. sylvestris, *Rorippa nasturtium-aquaticum, *Fumaria muralis, *Mentha x. piperita, *Hippeastrum puniceum, *Gladiolus cuspidatus, *Linum usitatissimum, *Mirabilis jalapa, *Polygonum arenastrum, *Plantago coronopus, *Artemisia vulgaris, *Cotula coronopifolia, *Vellereophyton dealbatum,* Ferns: _Pellaea falcata, Nephrolepis cordifolia_

Climbers: _Parsonsia straminea, *Anredera cordifolia, *Lonicera japonica, *Cardiospermum grandiflorum_

Aquatics: _*Sagittaria platyphylla_

Species restricted to permanent and transient sheets of water:

Graminoids: _Isolepis inundata, Paspalum distichum, *Isolepis prolifera, *Juncus capitatus, *Scirpus chlorostachys, *Polypogon monspeliensis_

Herbs: _Alternanthera denticulata_

Aquatics: _Typha orientalis, *Myriophyllum aquaticum, *Eichhornia crassipes, *Alternanthera philoxeroides_

Species restricted to graves:

Trees: _*Pinus halepensis, *Pinus pinaster, *Pinus pinea, *Pinus radiata, *Tristania conferta, *Eucalyptus melliodora, *Araucaria bidwillii, *Robinia pseudoacacia_

Shrubs: _Acacia myrtifolia, *Ulex europaeus, *Polygala myrtifolia, *Rhaphiolepis indica, *Lantana montevidensis_

Subshrubs: _*Pelargonium asperum_

Graminoids: _*Paspalum urvillei, *Crocosmia x. crocosmiiflora_

Herbs: _Diuris punctata, *Vinca major, *Lavandula stoechas, *Oxalis purpurea, *Allium neapolitanum, *Watsonia aletroides_

Succulents: _*Agave americana_

Species restricted to dumped soil, edges of roads, tracks:

Shrubs: _*Genista linifolia, *Acacia podalyriifolia_

Subshrubs: _*Solanum linnaeanum_

Graminoids: _Juncus vaginatus,*Agapanthus praecox_ subsp. _orientalis, *Triticum aestivum, *Chloris virgata, *Avena fatua, *Avena ludoviciana, *Avena sterilis,_

Herbs: _Suaeda australis, Calotis cuneifolia, Crassula sieberiana, Triptilodiscus pygmaeus, *Iris germanica, *Amaranthus hybridus, *Paronychia brasiliana, *Soliva anthemifolia, *Soliva sessilis, *Capsella bursa-pastoris, *Coronopus didymus, *Rapistrum rugosum, *Centranthus ruber, *Myosotis sylvatica, *Cichorium intybus, *Silybum marianum, *Tragopogon porrifolius, *Sisymbrium officinale, *Sisymbrium orientale, *Alyssum maritima, *Euphorbia peplus, *Chamaesyce prostrata, *Oxalis debilis_ var. _corymbosa, *Oxalis latifolia, *Papaver somniferum subsp. setigerum, *Lupinus_ spp., _*Arctotheca calendula, *Aster subulatus,_

our understanding of weed invasion and native persistence within a suburban matrix; d) some comparisons between the vegetation at the two sites; e) prior and subsequent surveys at the sites and the recording of rare species; and f) the current conservation status of the two sites.

a) Pre-1788 vegetation of Duck River and Rookwood

Benson _et al._ (1999) and Benson & Howell (2002) have suggested sources of information that can give us a picture of the landscape and vegetation at the time of European settlement in Australia. These include historical first-hand descriptions from journals, early letters and reports; material from museum collections and other systematic data collections; old paintings and photographs; and an area's remnant vegetation in context with climate and geology. Price has used the latter to draw a picture of the area as tall woodland or forest with trees that were 60–80 feet (18–24m) high, with an understorey that was grassy, but prone to invasion by shrubs when fire-free intervals were longer. He described Duck River and Rookwood vegetation in 1979 as 'disturbed' from their original vegetation, noting that 'regrowth' and the 'scattered, veteran eucalypts' still standing pointed to past woodland or forest structure. He described the variety of shrub species in the understorey in 1979, noting the range of species 'from plants such as _Kunzea ambigua_ and _Pultenaea villosa_ that grow well only in the open, somewhat exposed situations, to others such as _Glochidion ferdinandi, Breynia oblongifolia_ and _Notelaea longifolia,_ which are normally plants of wet, shaded forests'. He also noted the occurrence of shrub species more typical of sandstone soils, including _Asterolasia correifolia_, _Banksia spinulosa_, _Pultenaea retusa, Pomaderris lanigera_ and _Pomaderris ferruginea._ In summary, the native species were predominantly of a suite pertaining to clay based soils but with lesser numbers of species of a sandstone flora, particularly in Rookwood.

Price postulated that pre-1788 the area was dominated by _Eucalyptus moluccana_ and _Eucalyptus fibrosa_ while commenting on the diversity of tree species present at the sites, noting the presence in lower numbers of 'tree species from the drier west such as _Eucalyptus eugenioides, Eucalyptus parramattensis_ and _Eucalyptus longifolia'_ and that these 'mingle with others from wetter areas such as _Eucalyptus resinifera_ and _Syncarpia glomulifera'_. Of the trees he notes also the presence of 'those that grow best near to waterholes', such as _Angophora floribunda_ and _Eucalyptus amplifolia_ (the latter only at Duck River) and to species more typical of sandy soils 'such as _Angophora bakeri_, _Eucalyptus punctata_ and _Eucalyptus sclerophylla'_. Price disputed Kartzoff's (1969) idea of the area as one of blackbutt and Sydney blue gum (_Eucalyptus pilularis – Eucalyptus saligna_) high forest extending as far west as Merrylands and Granville. Rather, he agreed with Pidgeon's (1941) picture of assemblages of forest species typically found on clay shales that she recorded from the Bankstown-Liverpool district. Price's interpretation accords with Benson & Howell's (1990a, b) and Tozer's (2003 & 2010) reconstructions of the vegetation across the Cumberland Plain.

b) Vegetation dynamics – fire, moisture and light

Price described the scenario of 'too-frequent fires' reducing species diversity at both sites, noting that species with longer primary juvenile periods need fire-free intervals long enough to be able to flower and fruit before a subsequent fire, so as not to 'exhaust the gene pools'. He noted the succession dynamics of the vegetation in response to fire frequency, drawing a picture of scrub or shrubby areas 'reverting' to eucalypt woodland in the absence of fire, while following fire these areas return to grassland, which in turn, is re-invaded by shrubs and trees if fire is long absent. His conclusions are consistent with current understanding of secondary succession dynamics and disturbance by fire, both locally in Cumberland Plain woodland (see for example, Watson et al. 2009) and at a global scale (see Bond *et al.* 2005).

Price noted a bias towards *Melaleuca* species at the expense of eucalypts under regimes of frequent fire. He also noted that tree species that were quicker to reach reproductive maturity, such as *Angophora bakeri, Angophora floribunda, Eucalyptus eugenioides* and *Eucalyptus globoidea,* or those that had fire resistant bark (*Syncarpia glomulifera, Eucalyptus longifolia* and *Eucalyptus resinifera*), were able to 'persist better' under frequent fire, compared to those he states were 'more fire sensitive'. He suggested frequent fire as the cause of the decline in numbers of the once dominant *Eucalyptus moluccana,* seen at Rookwood but not Duck River.

The regular cool hazard reduction grass fires that had previously occurred every 2 years across large areas of Rookwood Cemetery had become less frequent by the mid-1970s according to Price, owing to tightening of the Environment Protection Authority's air pollution regulations (Price 1979). In 2001 a large, uncontrolled fire occurred in the eastern conservation area (Cemetery Areas 8, 27 and 28) and occasional small arson fires are currently reported by grounds staff at Rookwood cemetery (Glenn Piggott, pers. comm). The Duck River Reserve was not subject to such regular, deliberate burning in its earlier years, and the greater species richness recorded there may reflect this. However, in the 1980s it was noted with concern that some areas of the Duck River Reserve were subject to spot fires as frequently as annually (Price, G.A. cited in Greening Australia 1990). Parramatta City Council (2012) reports that for decades the reserve has been subject to arson fires 'at least every 2 years somewhere in the reserve' (David Kuhle, pers. comm.).

Price made reference to the 'vigorous growth habits' of the *Melaleuca* species outcompeting other species for light, forming 'dense stands' and 'suppressing competitors', particularly noting *Melaleuca nodosa,* which he described as 'aggressive and tolerant'. Even today at these sites, species of *Melaleuca,* particularly *Melaleuca nodosa,* develop large seed loads and recruit continuously, with adequate moisture, to develop a mixture of age cohorts in the field. They are seen colonising bare areas, eventually forming dense thickets and casting shade that suppresses much recruitment beyond the seedling stage (Hewitt unpub. doctoral studies). Price (1979) wrote that 'few plants other than tough herbs…and a few tufts of tolerant grasses…' were able to '…linger on in the dense shade' (of the *Melaleuca*). Price described 'the struggle to reach the canopy' with competition for light, and the way in which eucalypts, in contrast to *Melaleuca*, 'open up' the canopy somewhat allowing in light. This concurs with Bale *et al.* (1998) who remark that eucalypts have an open canopy structure and leaves of a pendant habit, allowing more direct and scattered light into the subcanopy. It is because of these growth habits that Price, while cautioning against too frequent a fire regime, reported fire as 'necessary to keep the ti-tree in check'.

'Niche partitioning' according to light and moisture levels was evident to Price in the distribution of grass species at the two sites. He wrote: 'At the most exposed, seasonally driest end of the spectrum in grassy glades *Themeda australis* may be dominant; in moister areas of dappled shade *Microlaena stipoides* is most common; between the 2 extremes there tends to be a mixed stand with *Microlanea stipoides, Entolasia marginata, Echinopogon ovata* and *Echinopogon caespitosus* more frequent in sheltered sites while in exposed places *Danthonia species, Aristida vagans, Stipa species,* particularly *Stipa nervosa, Dichelachne sciurea* and *Eragrostis brownii* are more common'. He noted also native *Agrostis* species present at the moistest sites while '*Dichelachne sciurea, Eragrostis brownii* and *Aristida vagans* are more successful at drier sites' (Price 1979). Price's idea of niche partitioning in the grassy layer, according to light and moisture levels, warrants further study, and has implications particularly for restoration efforts in grassy woodland communities.

c) Exotic species

The origin of the exotic species that Price recorded at the sites is interesting, with a number of those from Rookwood naturalised from cultural plantings at the site (e.g. 11 tree and palm species are restricted to graves). Exotic species used from the cemetery's inception to achieve a Victorian-Edwardian gardenesque style included formal avenues of *Phoenix canariensis, Pinus* and *Araucaria* species. Other exotics now growing in Rookwood were probably once planted over graves for their religious or Victorian funereal symbolism. These include perfumed species like honeysuckle (*Lonicera japonica*) representing innocence or sweetness of disposition, climbers or vines like Chinese wisteria (*Wisteria sinensis*) and morning glory (*Ipomoea indica*) to signify the bonds of love, roses for sinlessness, lilies for purity, and the varied palms and cedars for their biblical and quaranic connotations (Burke & Betteridge 1989). *Pinus* and *Cupressus*, 'evergreen' species, have symbolised the afterlife or life everlasting since Roman times. Many of these species now fall into the category of major weeds within the cemetery. UBM (2011) list problematic weeds within the cemetery as hawthorn (*Raphiolepis indica*) and privet (*Ligustrum sinense*), both of which were planted as hedges in the cemetery from the 1870s; *Coreopsis lanceolata, Watsonia meriana 'Bulbilifera'* (widely used as grave planting in the late 1800s), Camphor laurel (*Cinnamomum camphora*), freesia, bridal creeper (*Asparagus asparagoides*), Crofton weed (*Ageratina adenophora*), blue periwinkle (*Vinca major*),

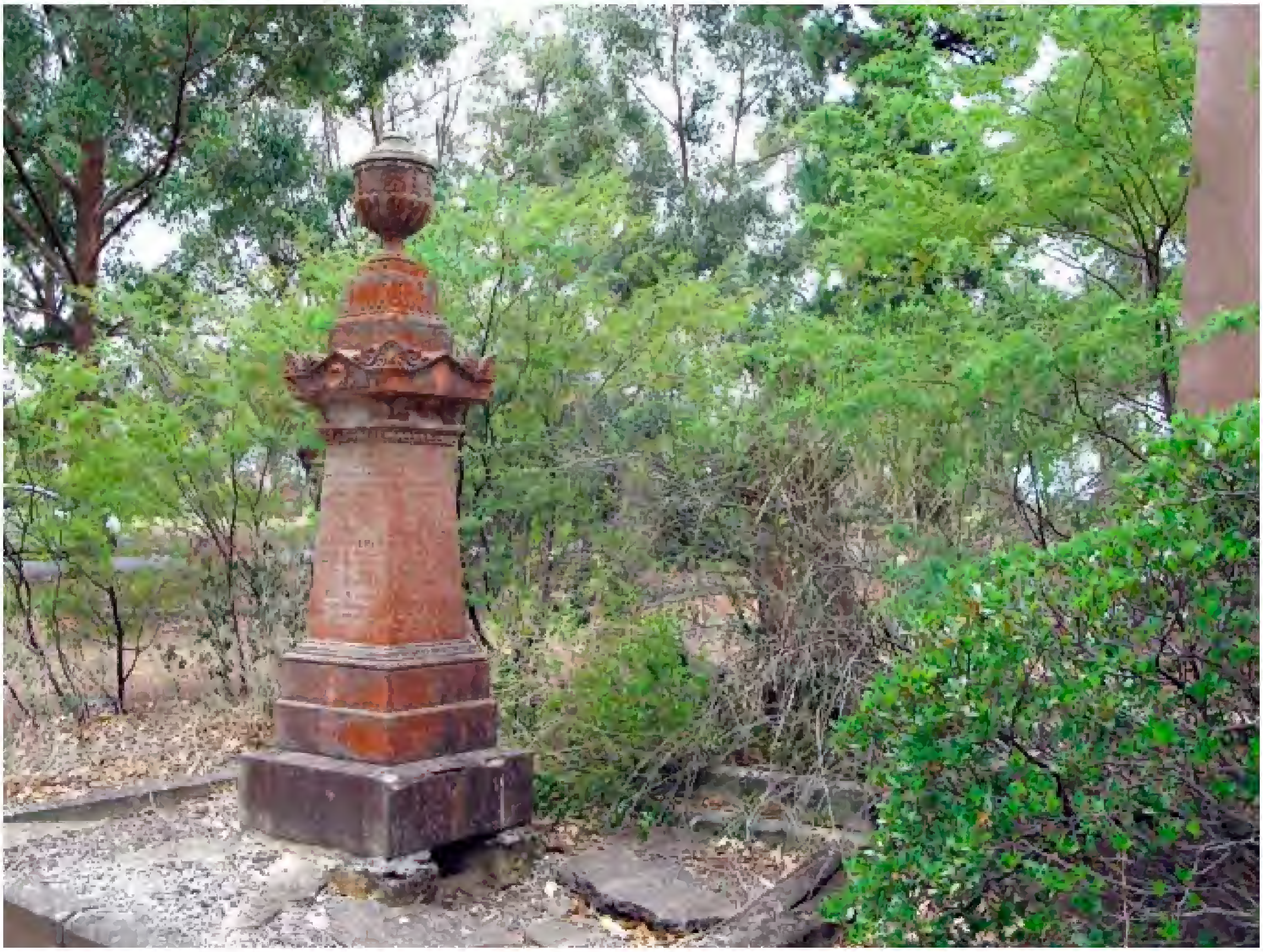


Fig. 5. The endangered species *Acacia pubescens* is seen here regenerating at Rookwood amongst graves and exotic species (*Rhaphiolepis indica* to the right).

lantana (*Lantana camara* and *Lantana montevidensis*), boneseed (*Chrysanthemoides monilifera* subsp. *monilifera*), blackberry (*Rubus spp*.), castor oil plant (*Ricinus communis)*, pampas grass (*Cortaderia selloana*), prickly pear (*Opuntia stricta*) and water hyacinth (*Eichhornia crassipes*).

Some Eucalypts from other parts of Australia have naturalised at Rookwood following planting of a few individuals e.g., *Eucalyptus saligna* (Sydney Blue Gum), *Eucalyptus punctata* (Grey Gum), *Eucalyptus melliodora* (Yellow Box), *Eucalyptus microcorys* (Tallowwood) and *Eucalyptus citriodora* (Lemon-scented Gum).

Some of the exotic tree species Price recorded at Duck River may also originate from deliberate plantings, with some traced to the time immediately following Parramatta City Council's acquisition of the land in 1946, e.g., *Erythrina sykesii* (Indian coral tree), *Salix babylonica* (weeping willow), *Populus nigrus* (poplar) and *Cinnamomum camphora* (camphor laurel) (EDAW 1996).

At the time of Price's work many of the exotic species were only present in drainage lines, on dumped soil and on the edges of roads and tracks (Tables 4a and 4b). This is a picture commonly seen in urban bushland such as the Duck River and Rookwood sites today, where run-off increases soil nutrients and moisture levels, favouring the growth of weeds (see discussion in Benson & Howell 1990a). By contrast, the areas with the lowest percentage of exotics (Tables 3 and 4a) are the core bushland areas Price termed Duck River woodland and Ti-tree and eucalypt scrub. This, too, is in accordance with what we know about the resilience of unploughed stands of native vegetation and priority effects. In assessing the impact of clearing and grazing history on the species composition of Cumberland Plain woodland remnants, Hill *et al.* (2005) found that clearing with soil disturbance had the highest impact on native species decline and exotic invasion, with grazing alone not dramatically impacting on composition. Price expressed it more colloquially from his own observations (page 10): 'Most of the original species no doubt still occur as clearing with axe and fire without years of laborious grubbing and weeding is somewhat akin to sowing dragon's teeth. The native species able to regenerate from rootstocks, lignotubers and stumps….'.

The abundance and microenvironment data for the exotic species that Price recorded in the 1970s provides a

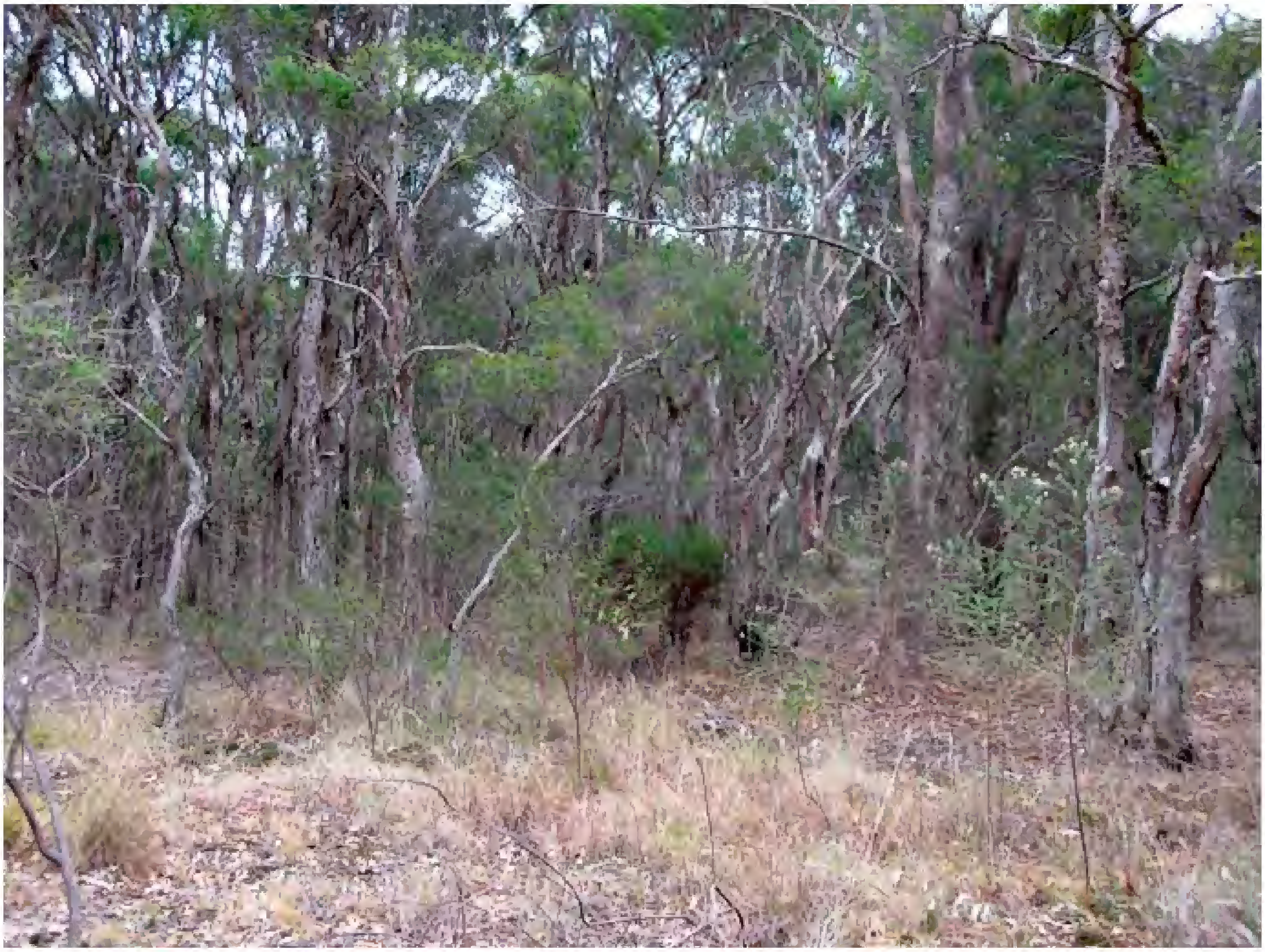


Fig. 6. A species rich woodland understorey at Duck River Reserve in South Granville where Tony Price recorded many native species. In Summer the pretty green flowers of *Callistemon pinifolius* and the dark blue fruits of *Polyscias sambucifolia* can be seen in the shrub layer. Diverse native groundcovers and herbs include *Brunoniella australis*, *Bossiaea prostrata*, *Vittadinia muelleri*, *Dichondra repens*, *Glycine clandestina*, *Desmodium varians*, *Polymeria calycina*, *Caesia parviflora*, and *Astroloma humifusum*.

comparison with the present. For example, he recorded *Vinca major* as only occasional at Rookwood over graves, and *Rhaphiolepis indica* as rare; both are now considered common and problematic weeds across the site. The major weeds today include a number of significant ones not recorded by Price, including (at Rookwood) *Andropogon virginicus* (Whisky grass), *Olea europaea* subsp. *cuspidata* (African olive), *Eragrostis curvula* (African lovegrass), *Hypericum perforatum* (St. John's wort), *Cytisus scoparius* (English broom) and *Grevillea robusta.* At Duck River, *Thunbergia alata* (Black-eyed Susan), *Passiflora edulis* (Common passionfruit), *Ipomoea cairica* (Coastal Morning Glory) and *Acetosa sagittata* (Rambling Dock) are additional exotic vines along the riverbanks. *Olea europea* and *Eragrostis curvula* in particular have established widely elsewhere in western Sydney since the 1970s (Doug Benson pers. comm. 2012) and indicate the short time spans over which invasion and vegetation change can occur.

d) Differences between Rookwood and Duck River

Price noted that a number of ground orchids (*Diuris, Microtis* and *Thelymitra*) associated particularly with the *Themeda* grasslands at Rookwood were not present at Duck River. He suggested that these species had survived at Rookwood and not Duck River, due to different landuse histories, Rookwood with its many decades of protection from stock grazing while still exposed to frequent burning. Native geophytes of grassy woodlands are now rare, although frequently found in cemeteries where they are not at risk from stockgrazing, but still vulnerable to lawnmowers, herbicides and 'tidying up' (Loneragan 1975, Semple-Kerr 1985, McBarron *et al.* 1987, Barrett & Barrett 2001). Sadly, the area of *Themeda* grassland that Price noted as rich in native Liliaceae and Orchidaceae (he mapped it later in 1993) has since disappeared under a monoculture of kikuyu (*Pennisetum clandestinum*) and the neatly rowed headstones of a lawn cemetery.

Price noted the many species in common to both sites, but pointed to higher numbers of naturalised exotics and a suite of native species more commonly found on sandstone substrates, that were collected from Rookwood. Sorensen's index of similarity shows a moderate degree of similarity in species assemblage between the two sites; 0.649 or 65% for all species, 0.662 or 66% for native flora and 0.635 or 64% for exotic flora. By comparison, Analyses of Similarity of quadrat data collected from seven remnant Cumberland Plain Woodland sites across western Sydney (French *et al.* 2000) showed similarities of 25–49% (Bray-Curtis dissimilarity scores of 51–75%). The lower similarity amongst these sites compared with the higher proportion of species shared at Duck River and Rookwood in the late 1970s might have a number of causes. Possibly the sites assessed by French *et al.* (2000) are of different sizes, with different edge effects and different propagule pressures; or that they have been subject to different disturbance factors; or that the intervening decades between Price's surveys and this later work has enabled greater divergence in species composition to have occurred. It would be worthwhile to recalculate similarity indices at Duck River and Rookwood today. Such data may even inform our understanding of species persistence traits against historical filtering by a range of disturbance types.

Most of the difference in species assemblage between Rookwood and Duck River is in the herb, shrub and graminoid growth forms (consistent with the French *et al* (2000) finding that differences between Cumberland Plain remnant sites were mainly due to differences in understorey species). The Rookwood/ Duck River comparison is unusual, (as noted by Price) in the higher number of exotic tree species at Rookwood, having naturalised from deliberate grave plantings.

Benson and Howell (2002) draw a picture from varied historical sources of Cumberland Plain woodland species assemblages being fairly continuous before European colonisation. Without major geographical boundaries to divide the plain, species would have been distributed reasonably uniformly. This they contrast with coastal rainforest communities that are naturally dissected (by soil and landscape features), resulting in species compositions that can vary markedly from site to site, with many isolated species occurrences. This latter type of variation in species occurrences is more in accordance with the picture Price recorded at Rookwood and Duck River and of the work of French *et al.* (2000), and is consistent with the species compositions given by Benson and Howell (2002) of Cumberland Plain remnants today. The local distribution and frequencies of species has changed and each remnant can

WILDLIFE PROTECTION AREA

This reserve has been declared a Wildlife Protection Area under Section 30(1)(b) of the NSW Companion Animals Act 1998

Dogs must be on a lead and stay on established tracks within this reserve
Cats are prohibited from entering this reserve

On-the-spot penalties apply
For more information contact 9806 5700

Fig.. 7. Parramatta City Council and the community have a strong commitment to caring for the woodland at Duck River and council recently declared the Duck River Reserve a Wildlife Protection Area prohibiting cats or dogs off leashes.

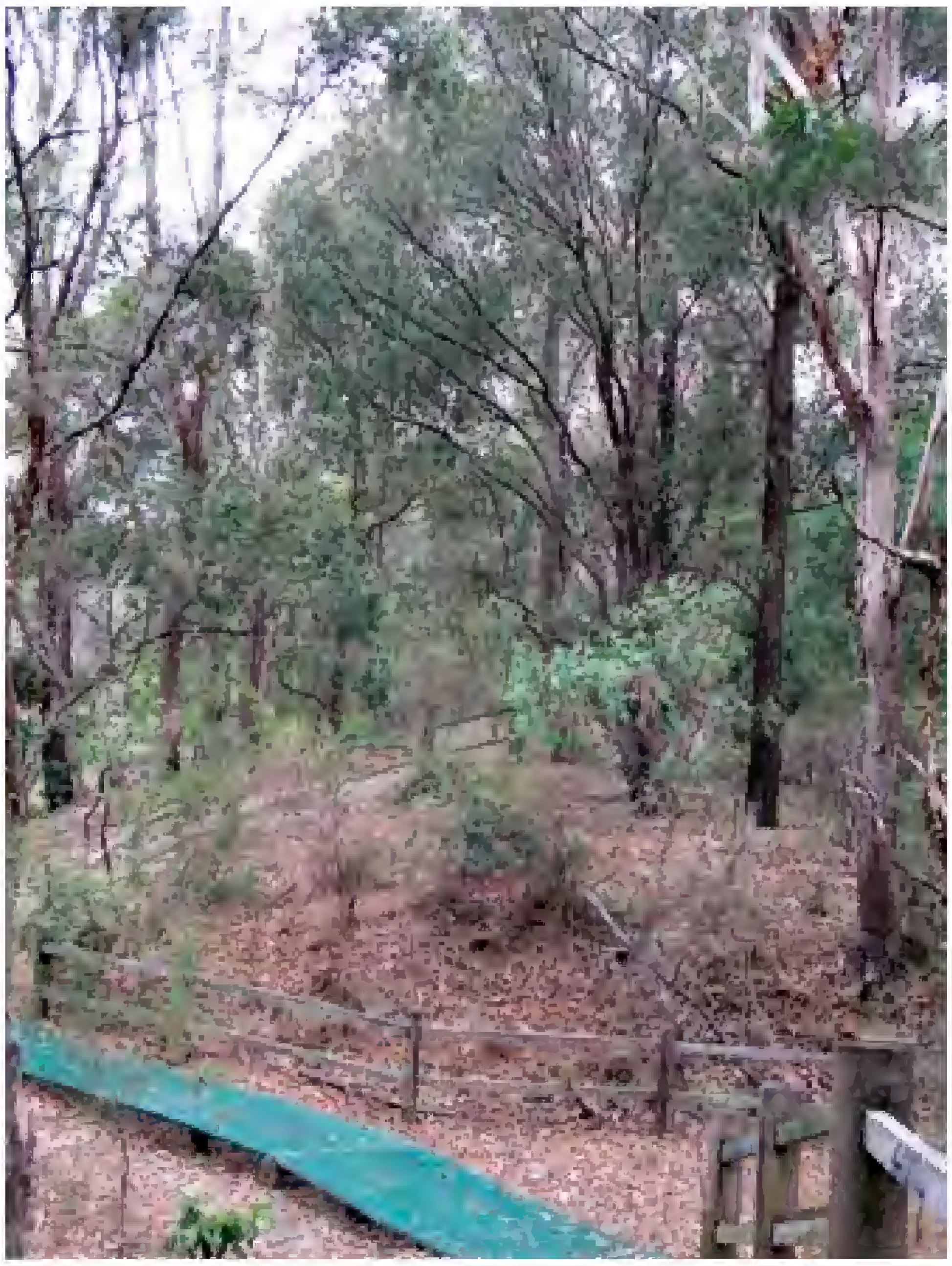


Fig. 8. Parramatta City Council now maintains tracks and fencing at Duck River to minimise erosion and protect the area from trail bike riders as was initially proposed by the Friends of Duck River under Tony Price.

hold different sets of once widespread species. Remnants differ in composition due to fragmentation, differing disturbance histories and chance survivals in some, with species made rare by virtue of their being confined to just a few sites. This is another reason that these small remnants of native vegetation are of great conservation value.

e) Surveys and rare species

Smith & Smith (1999) compiled a list of plant species recorded in Rookwood up to 1999 (i.e. their own survey plus Price (1979), Mount King Ecological Survey (1992), Quality Environmental Management (1994) and Teresa James (NPWS (1997)). They listed 608 species for Rookwood, 327 native and 281 exotics, including 115 native and 95 exotic species recorded since 1979. The additional species may indicate surveys of more stringent sampling design, but may also indicate vegetation change. Certainly the many additional exotic species recorded in the decades since 1979 indicate additional weed encroachments. It is also noted that while Price recorded a large number of grasses present in the cemetery in the late 1970s he did make a note to the effect that ‘graminae, poorly collected, Rookwood’, and the list of grasses (now Poaceae) has been added to substantially in later years.

Smith & Smith (1999) noted also that several native species, collected from Rookwood prior to Price’s work (known from old herbarium records), were not recorded by him, nor have been since, and are almost certainly no longer there – these include *Tetratheca juncea* and *Bothriochloa biloba* lodged in 1913 and 1935, respectively. There are also a small number of species recorded from Rookwood cemetery before and after Price’s surveys that do not appear in his lists e.g., *Dianella revoluta* 1973 & 1995; *Boronia polygalifolia* 1912 & 1997; and *Calotis lappulacea* 1887 & 1992 (lodged records viewed via Australia’s virtual herbarium website). It may be that these species did not flower and were therefore cryptic and/ or simply overlooked by Price at the time of his surveys. It should be noted that, at the time of Price’s work, plant identification was a considerably greater challenge without access to experts and herbarium collections, and that while Beadle, Carolin and Evans’ *Flora of the Sydney Region* (1972) provided a major spur to field botany, there were not the many flora guidebooks or electronic resources that have become available since.

No prior or subsequent flora survey of Duck River has been located that is as comprehensive as that of Price (1979). In herbaria across Australia there exist only a few dozen specimens from Duck River that predate the work of Price, among them material collected by Robert Brown in 1802, Joseph Maiden 1887, A.A. Hamilton 1909, and R. Coveny, D. Benson and H. Bryant 1976 (Australia’s virtual herbarium website). And the few surveys since Price (e.g., Greening Australia 1990, NPWS 1997, Applied Ecology 2011), aside from verifying the dominant and common species in the field, all acknowledge that they are largely based on Price’s 1979 account.

f) Conservation status of the sites today

The National Trust recognises Rookwood as a cemetery of World Heritage significance for both its cultural and nature conservation values. It is listed on the Register of the National Estate and under the NSW Heritage Act. While there is enormous pressure on all land within the cemetery for burial space, the vegetation conservation areas are also protected under the *Rookwood Necropolis Property Management Plan 2002*, which is a statutory document under the *NSW Threatened Species Conservation Act, 1995.* The Plan of Management recognises the regional significance of the remnant indigenous vegetation, and as a part of the fabric of the cemetery to be preserved and maintained (Rookwood Visual Significance Study 2010). Whilst it has not received the same level of external recognition, the Duck River Reserve in the Parramatta Local Government Area at South Granville is zoned 2EC for conservation, with strong council commitment to impact management and overall protection.

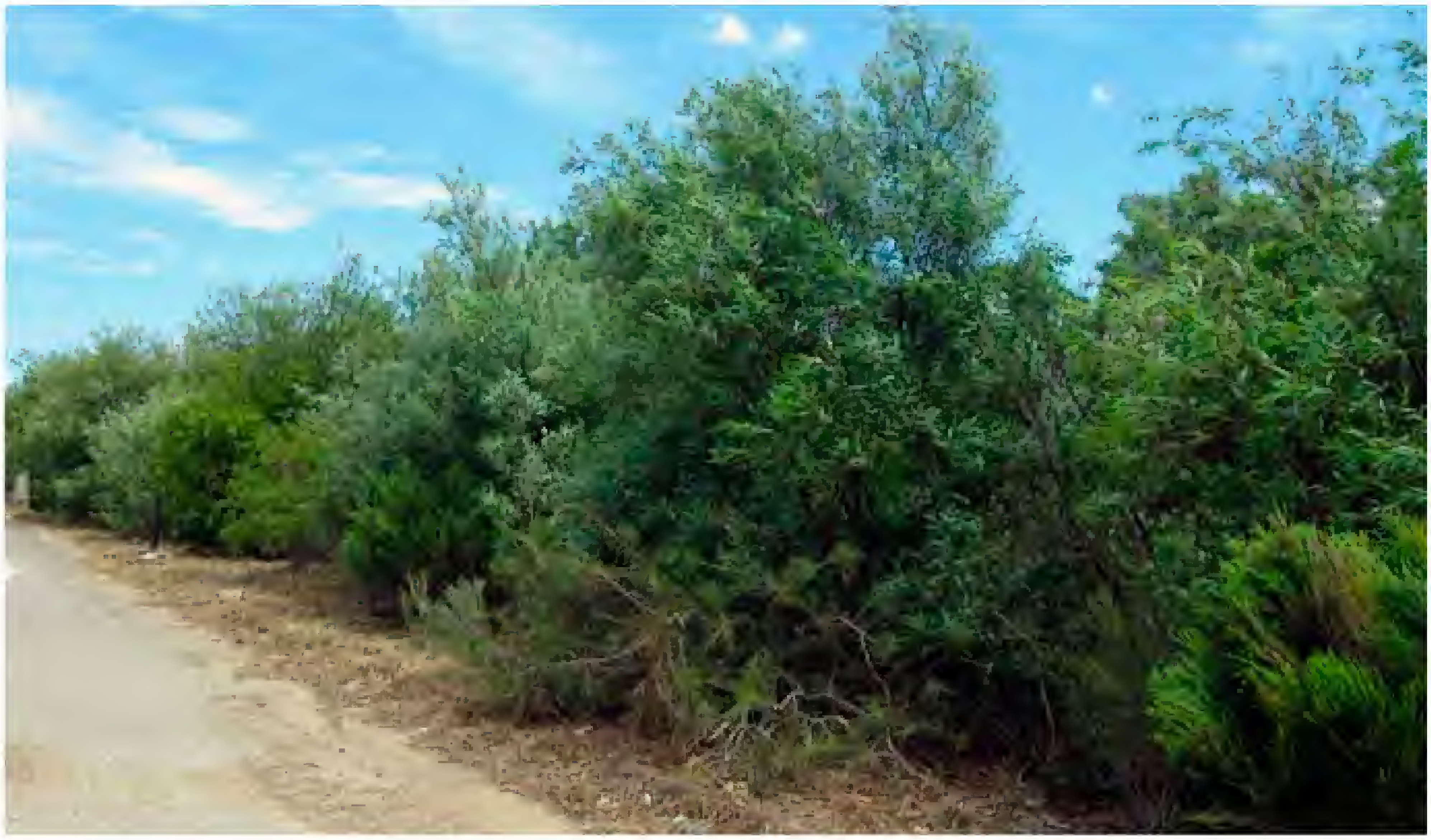


Fig. 9. Rookwood roadside native plantings: A number of perimeter and roadside plantings made within the cemetery since 2005 comprise native species grown from seed collected on site and germinated in the Rookwood Necropolis Joint Committee's nursery located on Hawthorne Avenue. In this planting – *Melaleuca thymifolia*, *Melaleuca erubescens*, *Dillwynia sieberi*, *Callistemon linearis*, *Acacia pubescens*, *Acacia longifolia*.

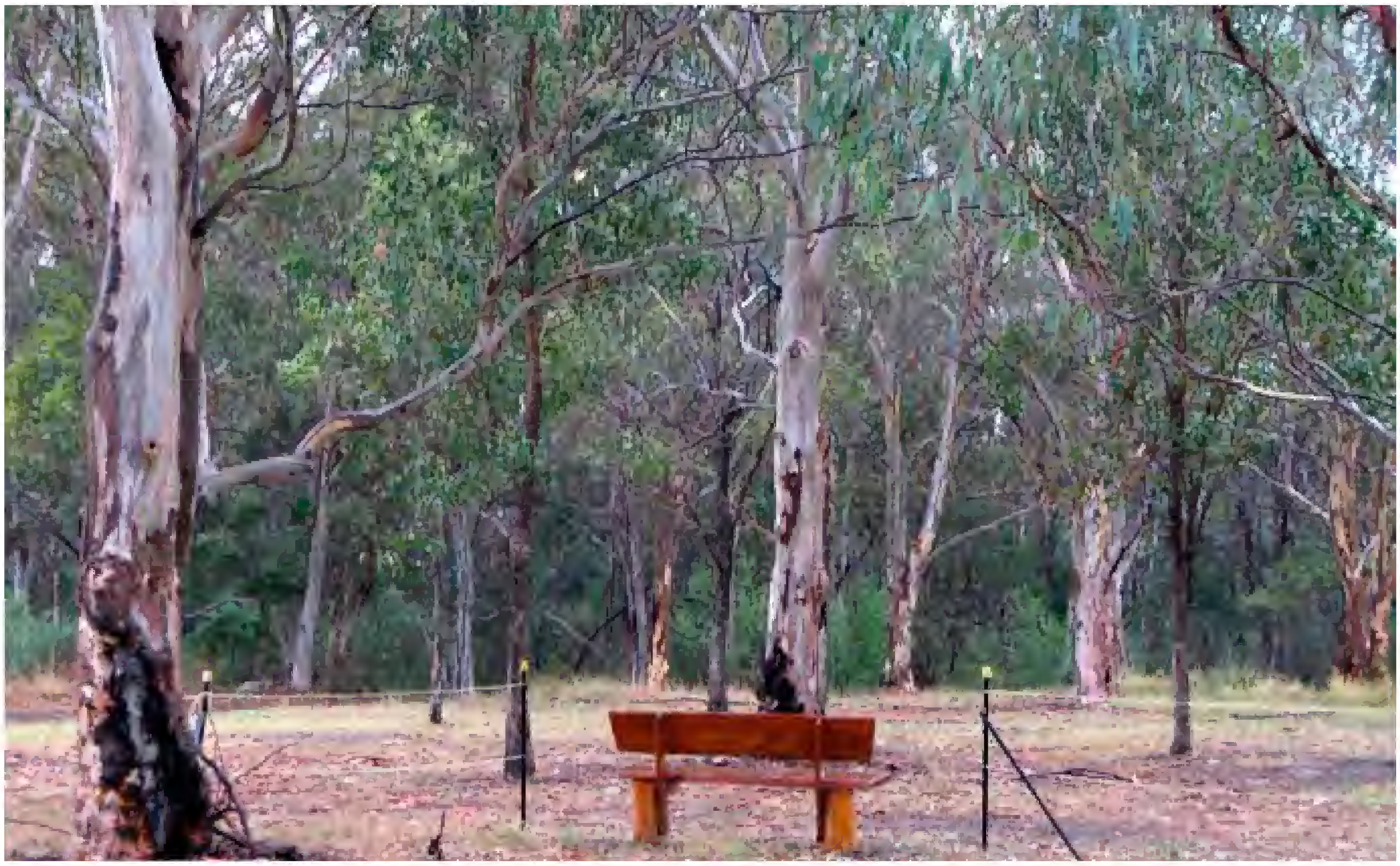


Fig. 10. At the Wellington Road end of the Duck River Reserve a wooden seat dedicated to the memory of Tony Price has been placed looking into the stately *Eucalyptus amplifolia*. Further into the reserve the track winds past *Eucalyptus moluccana*, *Eucalyptus fibrosa*, *Eucalyptus longifolia* and an unusual stand of *Eucalyptus punctata*.

Conclusion

In the 1970s, at a time when major conservation efforts were being directed at broad scale issues such as the protection of mangroves, rainforests and the development of national park systems, Tony Price's work focussed on the details of remnant vegetation in an increasingly modified suburban landscape. He saw value in this for what it revealed about the past landscape, as well as the ongoing ecological patterns. He concentrated on the careful recording of plant species and observing the ecology of plant responses to environmental conditions such as moisture, shading and fire. As a result his work is a valuable record of the presence, distribution and abundance of plant species at Rookwood and Duck River in the late 1970s, useful for comparing with the present and future times, as well as providing a picture of the district's past as seen from that viewpoint in time.

His observations that rare native species could survive in small areas such as parts of cemeteries, in spite of human impact, highlighted the importance of small areas for conservation, and provided local conservation groups with arguments for improved protection and management of such sites. Similarly, his careful observations of the ecology of native and exotic species set the scene for the development of regeneration and management programs by local conservation groups in subsequent decades.

Fig. 11. Tony Price working with other volunteers at Duck River Reserve in January 1998.

Until his death in 2010 Tony Price was still being consulted for his botanical knowledge and ecological opinion which were held in high regard. His work is testament to the value of long term citizen science and community involvement in environmental management. Tony Price joins a long tradition in botany, and the natural sciences more broadly, of citizen contribution and amateur/ professional collaborations (see Gilbert 1982 for interesting examples).

Despite competing landuse priorities at both Duck River and Rookwood, these bushland remnants still survive and certainly remain worthy of protection. As Tony Price was deeply aware, they are important for their inherent conservation values, for the clues they can give us to the past, for the regionally rare and significant flora they hold, for dependent fauna, and as a source of genetic variability for seed banking, horticulture and revegetation projects.

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Appendix 1: List of species recorded, location and abundance data X = common, O = occassional, R = rare

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
aquatic	Alismataceae	* *Sagittaria platyphylla*	Sagittaria	* *Sagittaria graminea* var. *weatherbiana*		X					X			
aquatic	Amaranthaceae	* *Alternanthera philoxeroides*	Alligator weed	* *Alternanthera philoxeroides*								X		
aquatic	Brassicaceae	* *Rorippa nasturtium-aquaticum*	Watercress	* *Rorippa nasturtium-aquaticum*		O					O			
aquatic	Haloragaceae	* *Myriophyllum aquaticum*	Parrots Feather	* *Myriophyllum brasiliense*	R							R		
aquatic	Pontederiaceae	* *Eichhornia crassipes*	Water Hyacinth	*Eichhornia crassipes*	R							R		
aquatic	Typhaceae	*Typha orientalis*	Broadleaf Cumbungi	*Typha orientalis*	R	O						O		
climber	Apocynaceae	* *Araujia sericifera*	Moth Vine	* *Araujia hortorum*	O	O	O	O	O		O			
climber	Apocynaceae	*Parsonsia straminea*	Common Silkpod	*Parsonsia straminea*		R					R			
climber	Apocynaceae	*Tylophora barbata*	Bearded Tylophora	*Tylophora barbata*		O	O							
climber	Asparagaceae	* *Asparagus asparagoides*	Bridal Creeper	* *Myrsiphyllum asparagoides*	O	X	O	O			X			
climber	Asparagaceae	* *Asparagus plumosus*	Climbing Asparagus Fern	* *Asparagus plumosus*		R	R							
climber	Basellaceae	* *Anredera cordifolia*	Madeira Vine	* *Anredera cordifolia*		X					X			
climber	Bignoniaceae	* *Campsis x tagliabuana*	Trumpet Creeper	* *Campsis x tagliabuana*		R	micro-environment not recorded							
climber	Bignoniaceae	*Pandorea pandorana*	Wonga Wonga Vine	*Pandorea pandorana*		O	R				O			
climber	Caprifoliaceae	* *Lonicera japonica*	Japanese Honeysuckle	* *Lonicera japonica*	O	X					X			
climber	Convolvulaceae	* *Ipomoea indica*	Morning Glory	* *Ipomoea indica*	O	O					O			O
climber	Convolvulaceae	*Polymeria calycina*		*Polymeria calycina*	O	X	X	X	O	O				
climber	Fabaceae, Subfamily Faboideae	* *Dipogon lignosus*	Dolichos Pea	* *Dipogon lignosus*	R	R							R	R
climber	Fabaceae, Subfamily Faboideae	* *Wisteria sinensis*	Chinese Wisteria	*Wisteria sinensis*	R		micro-environment not recorded							

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
climber	Fabaceae, Subfamily Faboideae	*Desmodium varians*	Slender Tick-trefoil	*Desmodium varians*		X	X	X						
climber	Fabaceae, Subfamily Faboideae	*Glycine clandestina*		*Glycine clandestina*	O	X	X	X	X					
climber	Fabaceae, Subfamily Faboideae	*Glycine tabacina*		*Glycine tabacina*	O	O	O	O	O					
climber	Fabaceae, Subfamily Faboideae	*Hardenbergia violacea*	Purple Coral Pea	*Hardenbergia violacea*	X	X	X	X	X	O				O
climber	Fabaceae, Subfamily Faboideae	*Kennedia rubicunda*	Dusky Coral Pea	*Kennedia rubicunda*	X	O		X	O	O				
climber	Lauraceae	*Cassytha glabella*		*Cassytha glabella*	X			X						
climber	Lauraceae	*Cassytha pubescens*		*Cassytha paniculata*	X	X		X						
climber	Luzuriagaceae	*Eustrephus latifolius*	Wombat Berry	*Eustrephus latifolius*	R	O	O	O						
climber	Pittosporaceae	*Billardiera scandens*	Hairy Apple Berry	*Billardiera scandens*	R	O		O						
climber	Ranunculaceae	*Clematis aristata*	Old Man's Beard	*Clematis aristata*	R	O	R	O						
climber	Ranunculaceae	*Clematis glycinoides*	Headache Vine	*Clematis glycinoides*		O	R	O						
climber	Sapindaceae	* *Cardiospermum grandiflorum*	Balloon Vine	* *Cardiospermum grandiflorum*		X					X			
graminoid	Alliaceae	* *Agapanthus praecox* subsp. *orientalis*	Agapathus	* *Agapanthus orientalis*	R	R								R
graminoid	Amaryllidaceae	*Crinum pedunculatum*	Swamp Lily	* *Crinum pedunculatum*		R					R			
graminoid	Cyperaceae	* *Cyperus brevifolius*		*Cyperus brevifolius*		O			O		O			
graminoid	Cyperaceae	* *Cyperus eragrostis*		* *Cyperus eragrostis*	O	O			O		O			
graminoid	Cyperaceae	* *Cyperus tenellus*		*Cyperus tenellus*	O						O			O
graminoid	Cyperaceae	* *Isolepis prolifera*		* *Scirpus prolifera*	O							O		
graminoid	Cyperaceae	* *Scirpus chlorostachys*		* *Scirpus chlorostachys*	R							R		
graminoid	Cyperaceae	*Carex inversa*		*Carex inversa*		O			O					
graminoid	Cyperaceae	*Cyathochaeta diandra*		*Cyathochaeta diandra*	X		O	O	X				X	
graminoid	Cyperaceae	*Cyperus mirus*		*Cyperus mirus*		R					R			
graminoid	Cyperaceae	*Gahnia aspera*	Rough Saw-sedge	*Gahnia aspera*		O		O			O			

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
graminoid	Cyperaceae	*Gahnia melanocarpa*	Black Fruit Saw-sedge	*Gahnia melanocarpa*		O		O						
graminoid	Cyperaceae	*Isolepis inundata*		*Scirpus inundatus*	O							O		
graminoid	Cyperaceae	*Lepidosperma laterale*		*Lepidosperma laterale*	O	X		X	O					
graminoid	Cyperaceae	*Ptilothrix deusta*		*Ptilanthelium deustum*	O				O				O	
graminoid	Cyperaceae	*Schoenus apogon*	Common Bog-rush	*Schoenus apogon*	O						O			
graminoid	Juncaceae	* *Juncus articulatus*		*Juncus articulatus*		O					O	O		
graminoid	Juncaceae	* *Juncus capitatus*		* *Juncus capitatus*	O							O		
graminoid	Juncaceae	*Juncus bufonius*	Toad Rush	*Juncus bufonius*		O					O	O		
graminoid	Juncaceae	*Juncus continuus*		*Juncus continuus*	O						O			
graminoid	Juncaceae	*Juncus fockei*		*Juncus fockei*	R				R		R			
graminoid	Juncaceae	*Juncus homalocaulis*		*Juncus homalocaulis*		R	R							
graminoid	Juncaceae	*Juncus planifolius*		*Juncus planifolius*	R	R					R	R		
graminoid	Juncaceae	*Juncus procerus*		*Juncus procerus*	R	R			R					
graminoid	Juncaceae	*Juncus sarophorus*		*Juncus sarophorus*	R	R			R					
graminoid	Juncaceae	*Juncus spp.*		*Juncus* sp. nov.	R				R					
graminoid	Juncaceae	*Juncus subsecundus*		*Juncus subsecundus*	R						R			
graminoid	Juncaceae	*Juncus usitatus*		*Juncus usitatus*	X	X			X		X			
graminoid	Juncaceae	*Juncus vaginatus*		*Juncus vaginatus*		R								R
graminoid	Lomandraceae	*Lomandra cylindrica*	Needle Mat-Rush	*Lomandra cylindrica*	O				O					
graminoid	Lomandraceae	*Lomandra filiformis*	Wattle Mat-rush	*Lomandra filiformis*	O	O		O	O					
graminoid	Lomandraceae	*Lomandra fluviatilis*	River Mat-Rush	*Lomandra fluviatilis*		O			O					
graminoid	Lomandraceae	*Lomandra gracilis*		*Lomandra gracilis*	X				X					
graminoid	Lomandraceae	*Lomandra longifolia*	Spiny-headed Mat-rush	*Lomandra longifolia*	O	O		O						
graminoid	Lomandraceae	*Lomandra multiflora* subsp. *multiflora*	Many-flowered Mat-rush	*Lomandra multiflora*		O		O						
graminoid	Phormiaceae	* *Phormium tenax*	New Zealand flax	* *Phormium cookianum*		R					R			
graminoid	Phormiaceae	*Dianella caerulea*	Blue Flax-lily	*Dianella caerulea*	X	X	R	O	X	R				
graminoid	Phormiaceae	*Dianella longifolia* var. *longifolia*		*Dianella laevis*	O			O	O					
graminoid	Phormiaceae	*Dianella revoluta*	Blue Flax-Lily	*Dianella revoluta*		O		O						
graminoid	Poaceae	* *Avena barbata*	Bearded Oats	* *Avena barbata*	X	X			O		X			X
graminoid	Poaceae	* *Avena fatua*	Wild Oats	* *Avena fatua*	R									R

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
graminoid	Poaceae	* *Avena ludoviciana*	Ludo Wild Oats	* *Avena ludoviciana*	R	R								R
graminoid	Poaceae	* *Avena sterilis*	Sterile Oats	* *Avena sterilis*	R									R
graminoid	Poaceae	* *Axonopus fissifolius*	Narrow-leafed Carpet Grass	* *Axonopus affinis*		R					R			
graminoid	Poaceae	* *Briza maxima*	Quaking Grass	* *Briza maxima*	O	O		O	O		O			O
graminoid	Poaceae	* *Briza minor*	Shivery Grass	* *Briza minor*	X	X		O	X		X			O
graminoid	Poaceae	* *Briza subaristata*		* *Briza triloba*		R			R					
graminoid	Poaceae	* *Bromus catharticus*	Prairie Grass	* *Ceratochloa unioloides*	O	X			O		X			O
graminoid	Poaceae	* *Bromus diandrus*	Great Brome	* *Bromus diandrus*	R	R		R	R					R
graminoid	Poaceae	* *Bromus molliformis*	Soft Brome	* *Bromus molliformis*		R					R			
graminoid	Poaceae	* *Bromus rubens*	Red Brome	* *Bromus rubens*		R					R			
graminoid	Poaceae	* *Chloris gayana*	Rhodes Grass	* *Chloris gayana*		R			R					
graminoid	Poaceae	* *Chloris virgata*	Feathertop Rhodes Grass	* *Chloris virgata*		R								R
graminoid	Poaceae	* *Cortaderia selloana*	Pampas Grass	* *Cordaueria selleana*		R					R			
graminoid	Poaceae	* *Dactylis glomerata*	Cocksfoot	* *Dactylis glomerata*		O			O					
graminoid	Poaceae	* *Digitaria ciliaris*	Summer Grass	*Digitaria ciliaris*		O			O		O			
graminoid	Poaceae	* *Digitaria sanguinalis*	Summer Grass	*Digitaria sanguinalis*		O			O					O
graminoid	Poaceae	* *Echinochloa crus-galli*	Barnyard grass	* *Echinochloa crus-galli*		O			O					O
graminoid	Poaceae	* *Ehrharta longiflora*	Annual Veldtgrass	* *Ehrharta longiflora*		R				R				
graminoid	Poaceae	* *Eleusine indica*	Crowsfoot Grass	* *Eleusine indica*		O			O	R				O
graminoid	Poaceae	* *Eleusine tristachya*	Goose Grass	* *Eleusine tristachya*		O			O					O
graminoid	Poaceae	* *Eragrostis curvula*	African Lovegrass	* *Eragrostis curvula*		R					R			
graminoid	Poaceae	* *Holcus lanatus*	Yorkshire Fog	* *Holcus lanatus*	R						R			
graminoid	Poaceae	* *Lolium multiflorum*	Italian Ryegrass	* *Lolium multiflorum*	X	X			O	O	O			X
graminoid	Poaceae	* *Lolium perenne*	Perennial Ryegrass	* *Lolium perenne*	X	X			O	O	O			X
graminoid	Poaceae	* *Paspalum dilatatum*	Paspalum	* *Paspalum cilatatum*	X	X	R	O	X	X	X		X	X
graminoid	Poaceae	* *Paspalum quadrifarium*	Tussock Paspalum	* *Paspalum quadrifarium*		O				R	O			
graminoid	Poaceae	* *Paspalum urvillei*	Vasey Grass	* *Paspalum urvillei*	R								R	

Growth form	**Current Family**	**Current Name**	**Common Name**	**Price's species names**	**Cemetery**	**Duck River**	**Low woodland, Duck River**	**Ti-tree & eucalypt scrub**	**Grasslands**	**Exposed soils & subsoils**	**Drainage lines, permanent water edges**	**Permanent & transient sheets of water**	**Graves, RW cemetery**	**Dumped soil, road & track edges**
graminoid	Poaceae	* *Pennisetum clandestinum*	Kikuya grass	* *Pennisetum clandestinum*	X	X		R	X	O	X		O	X
graminoid	Poaceae	* *Pennisetum glaucum*	Pearl Millet	* *Setaria glauca*		R					R			
graminoid	Poaceae	* *Pennisetum macrourum*	African Feather Grass	* *Pennisetum macrourum*	X				X		O		X	X
graminoid	Poaceae	* *Phalaris aquatica*	Phalaris	* *Phalaris tuberosa*		O			O					O
graminoid	Poaceae	* *Phalaris minor*	Lesser Canary Grass	* *Phalaris minor*		O			O					
graminoid	Poaceae	* *Poa annua*	Winter Grass	* *Poa annual*	O	O			O		O			
graminoid	Poaceae	* *Poa pratensis*	Kentucky Bluegrass	* *Poa pratensis*		R			R					
graminoid	Poaceae	* *Polypogon monspeliensis*	Annual Beardgrass	* *Polypogon monspeliensis*	R	R						R		
graminoid	Poaceae	* *Setaria palmifolia*	Palm grass	* *Setaria palmifolia*		R					R			
graminoid	Poaceae	* *Setaria parviflora*		* *Setaria geniculata*	X	X	O	O	X		X			O
graminoid	Poaceae	* *Sorghum halepense*	Johnson Grass	* *Sorghum halepense*		R	micro-environment not recorded							
graminoid	Poaceae	* *Sorghum leiocladum*	Wild sorghum	* *Sorghum leiocladum*		R			R					
graminoid	Poaceae	* *Sporobolus africanus*	Parramatta Grass	* *Sporobolus africanus*	X	X				X				X
graminoid	Poaceae	* *Stenotaphrum secundatum*	Buffalo Grass	* *Stenotaphrum secundatum*	O	R					O			
graminoid	Poaceae	* *Triticum aestivum*	Common Wheat	* *Triticum aestivum*		R								R
graminoid	Poaceae	* *Vulpia bromoides*	Squirrel Tail Fescue	* *Vulpia bromoides*	X	X			X					X
graminoid	Poaceae	* *Vulpia myuros*	Rat's Tail Fescue	* *Vulpia myuros*	X	X			X					X
graminoid	Poaceae	*Amphibromus neesii*		*Amphibromus neesii*		R					R			
graminoid	Poaceae	*Aristida ramosa*	Purple Wiregrass	*Aristida ramosa*		R			R					
graminoid	Poaceae	*Aristida vagans*	Threeawn Speargrass	*Aristida vagans*	X	X		X	X					
graminoid	Poaceae	*Arundinella nepalensis*	Reedgrass	*Arundinella nepalensis*	R						R			
graminoid	Poaceae	*Austrodanthonia racemosa* var. *racemosa*		*Danthonia racemosa*		R		R						
graminoid	Poaceae	*Austrodanthonia setacea*	Smallflower Wallaby Grass	*Danthonia setacea*		O			O					
graminoid	Poaceae	*Austrostipa mollis*		*Stipa mollis*	R				R					

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graminoid	Poaceae	*Austrostipa pubescens*		*Stipa pubescens*	X	X		X	O					
graminoid	Poaceae	*Austrostipa rudis* subsp. *nervosa*		*Stipa nervosa*	X	X	R	X	X					
graminoid	Poaceae	*Austrostipa scabra*		*Stipa scabra*		O		O	O					
graminoid	Poaceae	*Bothriochloa macra*	Red Grass, Red-leg	* *Bothriochloa macra*		R		R	R					
graminoid	Poaceae	*Chloris truncata*	Windmill Grass	*Chloris truncata*		X			X		X			
graminoid	Poaceae	*Cymbopogon refractus*	Barbed Wire Grass	*Cymbopogon refractus*		R	R	R	R					
graminoid	Poaceae	*Cynodon dactylon*	Couch, Bermudagrass	* *Cynodon dactylon*	X	X			X	X	X			X
graminoid	Poaceae	*Deyeuxia quadriseta*		*Deyeuxia quadriseta*	X	X		O	X					
graminoid	Poaceae	*Dichelachne micrantha*	Shorthair Plumegrass	*Dichelachne sciurea*	X	X	O	O	X	O	X			O
graminoid	Poaceae	*Dichelachne rara*		*Dichelachne rara*		R			R					
graminoid	Poaceae	*Digitaria parviflora*	Small-flowered Finger Grass	*Digitaria parviflora*		O		O						
graminoid	Poaceae	*Echinopogon caespitosus*	Bushy Hedgehog-grass	*Echinopogon caespitosus*	X	X	X	X						
graminoid	Poaceae	*Echinopogon ovatus*	Forest Hedgehog Grass	*Echinopogon ovatus*	X	X	X	X						
graminoid	Poaceae	*Entolasia marginata*	Bordered Panic	*Entolasia marginata*		O	O	O	R	R	O			
graminoid	Poaceae	*Entolasia stricta*	Wiry Panic	*Entolasia stricta*	X	X	O	X	X	X				O
graminoid	Poaceae	*Eragrostis brownii*	Brown's Lovegrass	*Eragrostis brownii*	X	X			X	X				X
graminoid	Poaceae	*Eragrostis leptostachya*	Paddock Lovegrass	*Eragrostis leptostachya*		O			O					
graminoid	Poaceae	*Eriochloa pseudoacrotricha*	Early Spring Grass	*Eriochloa pseudoacrotricha*	R	R			R					
graminoid	Poaceae	*Imperata cylindrica*	Blady grass	*Imperata cylindrica*	X	X	O	O	O	O	X			
graminoid	Poaceae	*Joycea pallida*	Silvertop Wallaby Grass	*Danthonia pallida*	R						R			
graminoid	Poaceae	*Lachnagrostis aemula*	Blowngrass	*Agrostis aemula*	X	X		O	X		X			O
graminoid	Poaceae	*Lachnagrostis filiformis*		*Agrostis avenacea*	X	X		O	X		X			O
graminoid	Poaceae	*Microlaena stipoides*	Weeping Grass	*Microlaena stipoides*	X	X	X	X	X		X			
graminoid	Poaceae	*Notodanthonia longifolia*	Long-leaved Wallaby Grass	*Danthonia longifolia*		R	micro-environment not recorded							

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graminoid	Poaceae	*Notodanthonia tenuior*		*Danthonia purpurascens*	X	X		O	O	X				O
graminoid	Poaceae	*Oplismenus imbecillis*	Creeping Beard Grass	*Oplismenus imbecillis*		R	micro-environment not recorded							
graminoid	Poaceae	*Panicum simile*	Two-colour Panic	*Panicum simile*	R				R					
graminoid	Poaceae	*Paspalidium aversum*		*Paspalidium aversum*		R		R						
graminoid	Poaceae	*Paspalum distichum*	Water Couch	*Paspalum paspaloides*		O						O		
graminoid	Poaceae	*Phragmites australis*	Common Reed	*Phragmites australis*		X					X			
graminoid	Poaceae	*Poa affinis*		* *Poa affinis*	R	R			R		R			
graminoid	Poaceae	*Poa sieberiana* var. *sieberiana*	Snowgrass	*Poa sieberana* var. *sieberana*	O	O		O	O	O				
graminoid	Poaceae	*Sporobolus elongatus*	Slender Rat's Tail Grass	*Sporobolus elongatus*	O	O			O					
graminoid	Poaceae	*Themeda australis*	Kangaroo Grass, Durawi (D'harawal)	*Themeda autralis*	X	X	R	O	X	R	R			O
graminoid	Poaceae	*Urochloa foliosa*	Leafy Panic	*Brachiaria foliosa*		R					R			
graminoid	Xanthorrhoeaceae	*Xanthorrhoea resinosa*	grass tree	*Xanthorrhoea resinosa* ssp. *concava*	O	O	R	O	O		O		O	
graminoid	Iridaceae	* *Crocosmia x crocosmiiflora*	Montbretia	* *Crocosmia x crocosmiiflora*	R								R	
groundlayer fern	Adiantaceae	*Adiantum aethiopicum*	common maidenhair fern	*Adiantum aethiopicum*		X	R				X			
groundlayer fern	Adiantaceae	*Cheilanthes tenuifolia*	Rock Fern	*Cheilanthes tenuifolia*	X	X	X	X	O					
groundlayer fern	Adiantaceae	*Pellaea falcata*	sickle fern	*Pellaea falcata*		X					R			
groundlayer fern	Davalliaceae	* *Nephrolepis cordifolia*	Fishbone Fern	* *Nephrolepis cordifolia*	R						R			
groundlayer fern	Dennstaedtiaceae	*Pteridium esculentum*	Bracken, Gurgi (Cadigal)	*Pteridium esculentum*	R	O					O		R	
herb	Acanthaceae	*Brunoniella australis*	Blue trumpet	*Brunoniella australis*		X	X							
herb	Acanthaceae	*Brunoniella pumilio*	Dwarf Brunoniella	*Brunoniella pumilio*		O	O							
herb	Aizoaceae	* *Aptenia cordifolia*	Baby Sun Rose	* *Aptenia cordifolia*		O	O							
herb	Alliaceae	* *Allium neapolitanum*	Flowering Onion	* *Allium neapolitianum*	R								R	

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herb	Alliaceae	* *Nothoscordum borbonicum*	Onion weed	* *Nothoscordum inodorum*	X	O					X			O
herb	Amaranthaceae	* *Amaranthus hybridus*	Slim amaranth	* *Amaranthus hybridus*		O								O
herb	Amaranthaceae	*Alternanthera denticulata*	Lesser joyweed	*Alternanthera denticulata*		O						O		
herb	Amaryllidaceae	* *Hippeastrum puniceum*		* *Hippeastrum x equestra*		O					O			
herb	Amaryllidaceae	* *Leucojum aestivum*	Snowflake	* *Leucojum aestivum*		R					R			
herb	Amaryllidaceae	* *Narcissus pseudonarcissus*	Daffodil	* *Narcissus ?jonquilla*		R	R				R			
herb	Anthericaceae	*Arthropodium milleflorum*	Pale Vanilla-lily	*Arthropodium milleflorum*		O	O	O						
herb	Anthericaceae	*Caesia parviflora*	Pale Grass-lily	*Caesia parviflora*	O	X			X					
herb	Anthericaceae	*Caesia parviflora* var. *vittata*		*Caesia vittata*		O			O					
herb	Anthericaceae	*Laxmannia gracilis*	Slender Wire Lily	*Laxmannia gracilis*	O	O		O	O					
herb	Anthericaceae	*Thysanotus tuberosus*	Common Fringe Lily	*Thysanotus tuberosus*	O	O		O	O					
herb	Apiaceae	* *Apium graveolens*	Celery	* *Apium graveolens*		R					R			
herb	Apiaceae	* *Cyclospermum leptophyllum*	Slender Celery	* *Apium leptophyllum*	O	O			O		O			O
herb	Apiaceae	* *Foeniculum vulgare*	Fennel	* *Foeniculum vulgare*	R	X				R	X			R
herb	Apiaceae	* *Hydrocotyle bonariensis*		* *Hydrocotyle bonariensis*	R						R			
herb	Apocynaceae	* *Vinca major*	Greater Periwinkle	* *Vinca major*	O								O	
herb	Araceae	* *Zantedeschia aethiopica*	Arum Lily	* *Zantedeschia aethiopica*		R					R			
herb	Asparagaceae	* *Asparagus officinalis*	Asparagus	* *Asparagus officinalis*	R	X	R	X						
herb	Asteraceae	* *Ageratina adenophora*	Crofton Weed	* *Eupatorium adenophorum*	O	O		O			O			
herb	Asteraceae	* *Arctotheca calendula*	Capeweed	* *Arctotheca calendula*	X	X								X
herb	Asteraceae	* *Artemisia vulgaris*	Chinese Wormwood	* *Artemisia vulgaris*		X					X			
herb	Asteraceae	* *Aster subulatus*	Wild Aster	* *Aster subulatus*		X								X
herb	Asteraceae	* *Bidens pilosa*	Cobblers Pegs	* *Bidens pilosa*	X	X	O	O			X			
herb	Asteraceae	* *Bidens subalternans*	Greater Beggar's Ticks	* *Bidens subalternans*		O					O			

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herb	Asteraceae	* *Cichorium intybus*	Chicory	* *Cichorium intybus*		R								R
herb	Asteraceae	* *Cirsium vulgare*	Spear Thistle	* *Cirsium vulgare*	O	O		O			O			O
herb	Asteraceae	* *Conyza bonariensis*	Flaxleaf Fleabane	* *Erigeron bonariensis*	O	O	O	O		O				O
herb	Asteraceae	* *Conyza sumatrensis*	Tall Fleabane	* *Erigeron floribundus*	O	O						O		O
herb	Asteraceae	* *Coreopsis lanceolata*	Coreopsis	* *Coreopsis lanceolata*	X			O	X				X	
herb	Asteraceae	* *Facelis retusa*	Annual trampweed	* *Facelis retusa*	O	O	O	O						
herb	Asteraceae	* *Gamochaeta purpurea*	Purple Cudweed	* *Gnaphalium purpureum*	X	X	O	O	X					
herb	Asteraceae	* *Helianthus annuus*	Common Sunflower	* *Helianthus annuus*		O					O			O
herb	Asteraceae	* *Hypochaeris glabra*	Smooth Catsear	* *Hypochaeris glabra*	O	O	micro-environment not recorded							
herb	Asteraceae	* *Hypochaeris microcephala*	White Flatweed	* *Hypochaeris microcephala*	R					R				
herb	Asteraceae	* *Hypochaeris radicata*	Catsear, Flatweed	* *Hypochaeris radicata*	X	X	X	X	X					X
herb	Asteraceae	* *Silybum marianum*	Variegated Thistle	* *Silybum marinanum*		R								R
herb	Asteraceae	* *Soliva anthemifolia*	Dwarf Jo-jo,	* *Soliva anthemifolia*	O	O								O
herb	Asteraceae	* *Soliva sessilis*	Jo-jo, Bindyi	* *Soliva pterospermax*	O	O								O
herb	Asteraceae	* *Sonchus asper*	Prickly Sowthistle	* *Sonchus asper*	O	O		O						O
herb	Asteraceae	* *Sonchus oleraceus*	Common Sowthistle	* *Sonchus olearaceus*	X	X	O	X						
herb	Asteraceae	* *Tragopogon porrifolius*	Salsify, Oyster Plant	* *Tragopogon porrifolius*		R								R
herb	Asteraceae	* *Vellereophyton dealbatum*	White Cudweed	* *Gnaphalium candidissimum*	X						X			
herb	Asteraceae	*Brachyscome linearifolia*		*Brachycome angustifolia* A.Cunn. ex DC. var. *angustifolia*		O	O							
herb	Asteraceae	*Calotis cuneifolia*	Purple Burr-daisy	*Calotis cuneifolia*	O	X								X
herb	Asteraceae	*Calotis lappulacea*	Yellow Burr-daisy	*Calotis lappulacea*		O			O					
herb	Asteraceae	*Centipeda minima*	Spreading Sneezeweed	*Centipeda minima*		O					O			

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herb	Asteraceae	*Chrysocephalum apiculatum*	Common Everlasting	* *Helichrysum apiculatum*	X	X		O	X					
herb	Asteraceae	*Coronidium scorpioides*	Button Everlasting	* *Helichrysum scorpioides*	X	X		O	X					
herb	Asteraceae	*Cotula australis*	Common Cotula	*Cotula australis*	X	X		O	X					X
herb	Asteraceae	*Cotula coronopifolia*	Water Buttons	*Cotula coronopifolia*	X	X					X			
herb	Asteraceae	*Euchiton gymnocephalus*		* *Gnaphalium japonicum*	X	X	O	O	X					
herb	Asteraceae	*Lagenophora stipitata*	Blue Bottle-daisy	*Lagenophora stipitata*		X	X							
herb	Asteraceae	*Picris angustifolia subsp. angustifolia*		* *Picris hieracioides*		R	micro-environment not recorded							
herb	Asteraceae	*Pseudognaphalium luteoalbum*	Jersey Cudweed	* *Gnaphalium luteoalbum*	X	X	O	O	X					X
herb	Asteraceae	*Senecio hispidulus*	Hill Fireweed	*Senecio hispidulus*	O	X	X	X			X			
herb	Asteraceae	*Senecio linearifolius*	Fireweed	*Senecio linearifolius*		R		R						
herb	Asteraceae	*Senecio pinnatifolius* var. *pinnatifolius*		*Senecio lautus*	O	O			O					
herb	Asteraceae	*Senecio quadridentatus*	Cotton Fireweed	*Senecio quadridentatus*		O		O						
herb	Asteraceae	*Solenogyne bellioides*		*Solenogyne bellioides*		O		O						
herb	Asteraceae	*Triptilodiscus pygmaeus*	Common sunray	*Helipterum australe*		O								O
herb	Asteraceae	*Vernonia cinerea*		*Vernonia cinerea*		X	X	X						
herb	Asteraceae	*Vittadinia dissecta*		*Vittadinia triloba*		O		O						
herb	Asteraceae	*Vittadinia muelleri*		*Vittadinia muelleri*		O				O				
herb	Boraginaceae	* *Myosotis sylvatica*	Forget Me Not	* *Myosotis sylvatica*		R								R
herb	Brassicaceae	* *Alyssum maritima*	Sweet Alyssum	*Alyssum maritimum*		R								R
herb	Brassicaceae	* *Brassica fruticulosa*	Twiggy Turnip	* *Brassica fruticulosa*		O					O			
herb	Brassicaceae	* *Brassica juncea*	Indian Mustard	* *Brassica juncea*		O					O			
herb	Brassicaceae	* *Brassica rapa* subsp. *sylvestris*	Turnip	* *Braccica rapa* ssp. *campestris*		O					O			
herb	Brassicaceae	* *Capsella bursa-pastoris*	Shepherd's Purse	* *Capsella bursa-pastoralis*		O								O
herb	Brassicaceae	* *Coronopus didymus*	Lesser Swinecress	* *Coronopus didymis*	O	O								O
herb	Brassicaceae	* *Lepidium bonariense*		* *Lepidium bonariense*	O	O			O					O

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herb	Brassicaceae	* *Rapistrum rugosum*	Turnip Weed	* *Rapistrum rugosum*	O									O
herb	Brassicaceae	* *Sisymbrium officinale*	Hedge Mustard	* *Sisymbrium officinale*		R								R
herb	Brassicaceae	* *Sisymbrium orientale*	Indian Hedge Mustard	* *Sisymbrium orientale*		R								R
herb	Brassicaceae	*Cardamine lilacina*		*Cardamine intermedia*		O	O							
herb	Campanulaceae	*Wahlenbergia communis*	Tufted Bluebell	*Wahlenbergia communis*	X	X	X	X	X	O				
herb	Campanulaceae	*Wahlenbergia gracilis*	Sprawling Bluebell	*Wahlenbergia gracilis*	X	X	X	X	X					
herb	Campanulaceae	*Wahlenbergia stricta*	Australian Bluebell	*Wahlenbergia stricta*		R		R						
herb	Cannaceae	* *Canna indica*	Tous-les-mois Arrowroot	* *Canna indica*		R					R			
herb	Cannaceae	* *Canna* spp.		* *Canna* spp.		R					R			
herb	Caryophyllaceae	* *Cerastium glomeratum*	Mouse-ear Chickweed	* *Cerastium glomeratum*		O			O					
herb	Caryophyllaceae	* *Paronychia brasiliana*	Chilean Whitlow Wort	* *Paronychia brasiliana*	O									O
herb	Caryophyllaceae	* *Petrorhagia nanteuilii*		* *Petrorhagia nanteuilii*	X	X		X	X					
herb	Caryophyllaceae	* *Petrorhagia velutina*		* *Petrorhagia velutina*	O	X		X	X					
herb	Caryophyllaceae	* *Polycarpon tetraphyllum*	Four-leaved Allseed	*Polycarpon tetraphyllum*		O	O							
herb	Caryophyllaceae	* *Silene gallica* var. *gallica*		* *Silene anglica*	X	X			X					
herb	Caryophyllaceae	* *Spergularia rubra*	Sandspurry	* *Spergularia rubra*	O	O					O			
herb	Caryophyllaceae	* *Stellaria media*	Common Chickweed	* *Stellaria media*		O					O			
herb	Centrolepidaceae	*Centrolepis strigosa*		*Centrolepis strigosa*	R						R			
herb	Chenopodiaceae	* *Chenopodium album*	Fat Hen	* *Chenopodium album*	O	O		O						
herb	Chenopodiaceae	*Chenopodium trigonon*	Fishweed	*Chenopodium trigonon*	O	O					O			
herb	Chenopodiaceae	*Dysphania littoralis*		*Dysphania littoralis*		O				O				
herb	Chenopodiaceae	*Einadia hastata*	Berry Saltbush	*Rhagodia hastata*	O	X	X	X						
herb	Chenopodiaceae	*Einadia nutans* subsp. *linifolia*		*Rhagodia nutans*		O		O						
herb	Chenopodiaceae	*Einadia polygonoides*		*Chenopodium polygonoides*		O	O							
herb	Chenopodiaceae	*Suaeda australis*	Seablite	*Suaeda australis*	R									R

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
herb	Clusiaceae	*Hypericum japonicum*		*Hypericum japonicum*	O	X	O	O	O					O
herb	Commelinaceae	* *Tradescantia fluminensis*	Wandering Jew	* *Tradescantia albiflora*	O	X		R			X			
herb	Convolvulaceae	*Dichondra repens*	Kidney Weed, Yilibili (D'harawal)	*Dichondra repens*	X	X	X	X	X		X			
herb	Crassulaceae	* *Bryophyllum delagoense*	Mother-of-millions	?* *Bryophyllum tubiflorum*	R	R					R		R	
herb	Crassulaceae	* *Crassula multicava*		* *Crassula multicava*	R	R					R		R	
herb	Crassulaceae	* *Sedum praealtum*		* *Sedum praeltum*	R	R					R		R	
herb	Crassulaceae	*Crassula sieberiana*	Australian Stonecrop	*Crassula sieberana*	R									R
herb	Droseraceae	*Drosera peltata*		*Drosera peltata*	O	O					O			O
herb	Euphorbiaceae	* *Chamaesyce prostrata*	Red Caustic Weed	* *Euphorbia prostrata*		R								R
herb	Euphorbiaceae	* *Euphorbia peplus*	Petty Spurge	* *Euphorbia peplus*	R	R								R
herb	Euphorbiaceae	*Chamaesyce drummondii*		*Euphorbia drummondii*		O				O				
herb	Fabaceae, Subfamily Faboideae	* *Lotus angustissimus*	Slender Birds-foot Trefoil	* *Lotus angustissimus*	X	X		X	X					
herb	Fabaceae, Subfamily Faboideae	* *Lotus subbiflorus*	Hairy Birds-foot Trefoil	* *Lotus hispidus*	O				O					
herb	Fabaceae, Subfamily Faboideae	* *Medicago polymorpha*	Burr Medic	* *Medicago polymorpha*	X	X			X					X
herb	Fabaceae, Subfamily Faboideae	* *Medicago sativa*	Lucerne, Alfalfa	* *Medicago sativa*	R	R			R					R
herb	Fabaceae, Subfamily Faboideae	* *Melilotus indicus*	Hexham Scent	* *Melilotus indica*	O	O			O					O
herb	Fabaceae, Subfamily Faboideae	* *Trifolium arvense*	Haresfoot Clover	* *Trifolium arvense*	R	R			R					R
herb	Fabaceae, Subfamily Faboideae	* *Trifolium campestre*	Hop Clover	*Trifolium campestre*	O	O			O		O			O
herb	Fabaceae, Subfamily Faboideae	* *Trifolium dubium*	Yellow Suckling Clover	* *Trifolium dubium*	X	X			X		X			X

Growth form	**Current Family**	**Current Name**	**Common Name**	**Price's species names**	**Cemetery**	**Duck River**	**Low woodland, Duck River**	**Ti-tree & eucalypt scrub**	**Grasslands**	**Exposed soils & subsoils**	**Drainage lines, permanent water edges**	**Permanent & transient sheets of water**	**Graves, RW cemetery**	**Dumped soil, road & track edges**
herb	Fabaceae, Subfamily Faboideae	* *Trifolium glomeratum*	Clustered Clover	* *Trifolium glomeratum*	X	X			X		X			X
herb	Fabaceae, Subfamily Faboideae	* *Trifolium pratense*	Red Clover	* *Trifolium pratense*	R	R			R					R
herb	Fabaceae, Subfamily Faboideae	* *Trifolium repens*	White Clover	* *Trifolium repens*	X	X			X		O			O
herb	Fabaceae, Subfamily Faboideae	* *Vicia hirsuta*	Hairy Vetch	* *Vicia hirsuta*	O	O			O		O			O
herb	Fabaceae, Subfamily Faboideae	* *Vicia sativa*		* *Vicia sativa*	O	O			O		O			O
herb	Fabaceae, Subfamily Faboideae	* *Vicia sativa subsp. nigra*	Narrow-leaved Vetch	* *Vicia angustifolia*	O	O			O		O			O
herb	Fabaceae, Subfamily Faboideae	* *Vicia tetrasperma*	Slender Vetch	* *Vicia tetrasperma*	O	O			O		O			
herb	Fabaceae, Subfamily Faboideae	*Zornia dyctiocarpa*	Zornia	*Zornia dyctiocarpa*		R			R					
herb	Fumariaceae	* *Fumaria muralis*	Wall Fumitory	* *Fumaria muralis*	O	O					O			
herb	Gentianaceae	* *Centaurium erythraea*	Common Centaury	* *Centaurium erythraea*	X	X		O	X					
herb	Gentianaceae	* *Centaurium tenuiflorum*		* *Centaurium tenuiflorum*	X	X		O	X					
herb	Geraniaceae	*Pelargonium inodorum*		* *Pelargonium inodorum*	O	X	X	X						
herb	Goodeniaceae	*Goodenia bellidifolia*		*Goodenia bellidifolia*	X	X			X					
herb	Goodeniaceae	*Goodenia hederacea*	Forest Goodenia	*Goodenia hederacea*	X	X		X	X					
herb	Goodeniaceae	*Goodenia heterophylla*		*Goodenia heterophylla*	R			R						
herb	Goodeniaceae	*Goodenia paniculata*	Branched Goodenia	*Goodenia paniculata*	X	X					X			
herb	Goodeniaceae	*Scaevola albida*	Pale Fan-flower	*Scaevola albida*		O	O							
herb	Haloragaceae	*Gonocarpus tetragynus*		*Haloragis teragyna*	X	O		O	X					
herb	Hypoxidaceae	*Hypoxis hygrometrica*	Golden Weather-grass	*Hypoxis hygrometrica*	O	X			X					
herb	Iridaceae	* *Freesia hybrid*	freesia	* *Freesia refracta var. odorata*	O	O		O	O					

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
herb	Iridaceae	* *Gladiolus cuspidatus*		* *Gladiolus cuspidatus*	O	O					O			
herb	Iridaceae	* *Gladiolus marginatus*		* *Watsonia marginata*	O			O					O	
herb	Iridaceae	* *Iris germanica*	Tall Bearded Iris	* *Iris germanica*		R								R
herb	Iridaceae	* *Ixia ?capillaris*		* *Ixia ?capillaris*	O				O				O	
herb	Iridaceae	* *Ixia flexuosa*	corn lily	* *Ixia flexuosa*	O				O				O	
herb	Iridaceae	* *Ixia maculata*		* *Ixia x ?maculata*	O				O				O	
herb	Iridaceae	* *Romulea longifolia*	onion grass	* *Romulea longifolia*	X	X			X					
herb	Iridaceae	* *Sisyrinchium* sp. *A sensu James & Brown (1993)*	Scourweed	* *Sisyrinchium micranthum*	O	O					O			O
herb	Iridaceae	* *Sparaxis* spp.	Harlequin flower	* *Sparaxis* spp.		R			R					
herb	Iridaceae	* *Tritonia lineata*	Montbretia	* *Tritonia lineata*	X			X					X	O
herb	Iridaceae	* *Watsonia aletroides*		* *Watsonia alectroides*	R								R	
herb	Iridaceae	* *Watsonia meriana* (L.) Mill. *'Bulbillifera'*	Wild Watsonia	* *Watsonia bulbifera*	X	X			O		X			
herb	Iridaceae	* *Watsonia* spp.		* *Watsonia hybrids*	X			X					X	
herb	Iridaceae	*Patersonia longifolia*	Purple flag	*Patersonia longifolia*	X			X	X				X	
herb	Lamiaceae	* *Lavandula stoechas*	Italian Lavender	* *Lavandula ?vera*	R								R	
herb	Lamiaceae	* *Mentha x piperita*	Peppermint	* *Mentha x piperita*		O					O			
herb	Lamiaceae	* *Scutellaria racemosa*		* *Scutellaria racemosa*		X			X		X			
herb	Lamiaceae	* *Stachys arvensis*	Stagger Weed	* *Stachys arvensis*	O	X			X		X			
herb	Linaceae	* *Linum trigynum*	French Flax	* *Linum trigynum*	X	X		X	X					
herb	Linaceae	* *Linum usitatissimum*	Flax, Linseed	* *Linum usitatissimum*		R					R			
herb	Linaceae	*Linum marginale*	Native Flax	*Linum marginale*	O	O			O					
herb	Lobeliaceae	*Isotoma fluviatilis*	Swamp Isotoma	*Isotoma fluviatilis*		R					R			
herb	Lobeliaceae	*Lobelia anceps*		*Lobelia alata*	X	X	X	X	R					
herb	Lythraceae	*Lythrum hyssopifolia*	Hyssop Loosestrife	*Lythrum hyssopifolia*	O	O					O	O		
herb	Malvaceae	* *Malva parviflora*	Small-flowered Mallow	* *Malva parviflora*	O	O			O		O			O
herb	Malvaceae	* *Modiola caroliniana*	Red-flowered Mallow	* *Modiola caroliniana*	O	O			O		O			O
herb	Myrsinaceae	* *Anagillas arvensis*	Scarlet Pimpernel	* *Anagillas arvensis*	X	X					X			X

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herb	Nyctaginaceae	* *Mirabilis jalapa*	Four o'clock Flower	* *Mirabilis jalapa*		R					R			
herb	Orchidaceae	*Diuris aurea*		*Diuris aurea*	X			X	X					
herb	Orchidaceae	*Diuris maculata*	Spotted Doubletail	*Diuris maculata*	O	O		O	O					
herb	Orchidaceae	*Diuris punctata*	Purple Donkey Orchid	*Diuris punctata*	R								R	
herb	Orchidaceae	*Diuris sulphurea*	Tiger Orchid, Hornet Orchid	*Diuris sulphurea*	R	R		R	R					
herb	Orchidaceae	*Diuris sulphurea* var. *brevifolia*		*Diuris brevifolia*	X	O		X	X					
herb	Orchidaceae	*Microtis parviflora*	Slender Onion Orchid	*Microtis parviflora*	X			X	X					
herb	Orchidaceae	*Microtis unifolia*	Common Onion Orchid	*Microtis unifolia*	X			X	X					
herb	Orchidaceae	*Orthoceras strictum*	Bird's-mouth Orchid	*Orthoceras strictum*	R			R						
herb	Orchidaceae	*Pterostylis nutans*	Nodding Greenhood	*Pterostylis nutans*		R		R						
herb	Orchidaceae	*Thelymitra pauciflora*	Slender Sun Orchid	*Thelymitra pauciflora*	X	R		X	X					
herb	Oxalidaceae	* *Oxalis articulata*		* *Oxalis articulata*	R	R							R	R
herb	Oxalidaceae	* *Oxalis corniculata*		*Oxalis corniculata*	X	X	O	O	O					
herb	Oxalidaceae	* *Oxalis debilis* var. *corymbosa*		* *Oxalis corymbosa*	R	R								R
herb	Oxalidaceae	* *Oxalis latifolia*		* *Oxalis latifolia*	R	R								R
herb	Oxalidaceae	* *Oxalis pes-caprae*		* *Oxalis pes-caprae*	R	R					R		R	R
herb	Oxalidaceae	* *Oxalis purpurea*		* *Oxalis purpurea*	R								R	
herb	Papaveraceae	* *Papaver hybridum*	Rough Poppy	* *Papaver hybridum*		R					R			R
herb	Papaveraceae	* *Papaver somniferum* subsp. *setigerum*	Poppy	* *Papaver setigerum*		R								R
herb	Phyllanthaceae	*Poranthera microphylla*		*Poranthera microphylla*	X	X	X	X	O					
herb	Phytolaccaceae	* *Phytolacca octandra*	Inkweed	* *Phytolacca octandra*	O	O	O	O			O			
herb	Plantaginaceae	* *Plantago coronopus*	Buck's-horn Plantain	* *Plantago coronopus*	R						R			
herb	Plantaginaceae	* *Plantago lanceolata*	Lamb's Tongues, Plantain	* *Plantago lanceolata*	X	X			X	O	X			X
herb	Plantaginaceae	*Plantago varia*		* *Plantago varia*		X			X					
herb	Polygonaceae	* *Polygonum arenastrum*	Wireweed	* *Polygonum arenastrum*	R						R			

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herb	Polygonaceae	* *Polygonum aviculare*	Wireweed	* *Polygonum aviculare*	O	O				O				O
herb	Polygonaceae	* *Rumex conglomeratus*	Clustered Dock	* *Rumex conglomeratus*	O	O			O		O			O
herb	Polygonaceae	* *Rumex crispus*	Curled Dock	* *Rumex crispus*	X	X			O		X			O
herb	Polygonaceae	*Persicaria decipiens*	Slender Knotweed	*Polygonum decipiens*	O	X					X			
herb	Polygonaceae	*Persicaria lapathifolia*	Pale Knotweed	*Polygonum x lapathifolium*	R	R					R			
herb	Polygonaceae	*Rumex brownii*	Swamp Dock	*Rumex brownii*	O	O			O					O
herb	Portulacaceae	*Portulaca oleracea*	Pigweed, Purslane	* *Portulaca oleracea*	X	R			X				X	R
herb	Primulaceae	*Primula malacoides*	Fairy Primrose	*Primula malacoides*		R	micro-environment not recorded							
herb	Ranunculaceae	*Ranunculus lappaceus*	Common Buttercup, Yarrakalgamba (D'harawal)	*Ranunculus lappaceus*		R		R			R			
herb	Rubiaceae	* *Richardia stellaris*		* *Richardia stellaris*	O	O			O					
herb	Rubiaceae	*Opercularia diphylla*		*Opercularia diphylla*	O	X	O	X	O					
herb	Scrophulariaceae	* *Misopates orontium*	Lesser Snapdragon	* *Misopates orontium*	O	O			O					
herb	Scrophulariaceae	* *Veronica persica*	Creeping Speedwell	* *Veronica persica*	O	O					O			O
herb	Solanaceae	* *Solanum nigrum*	Black-berry Nightshade	* *Solanum nigrum*	O	X	X	X						
herb	Solanaceae	*Solanum americanum*	Glossy Nightshade	*Solanum nodiflorum*		R					R			
herb	Stackhousiaceae	*Stackhousia viminea*	Slender Stackhousia	*Stackhousia viminea*	X	X		X	X					
herb	Stylidiaceae	*Stylidium graminifolium*	Grass Trigger-plant	*Stylidium graminifolium*	X			X	X				X	
herb	Tropaeolaceae	* *Tropaeolum majus*	Nasturtium	* *Tropaeolum majus*	R	R		R						
herb	Valerianaceae	* *Centranthus ruber*	Red Valerian	* *Cetranthus ruber*		O								O
herb	Verbenaceae	* *Verbena bonariensis*	Purpletop	* *Verbena bonariensis*	X	X		O	O		X			O
herb	Verbenaceae	* *Verbena officinalis*	Common Verbena	*Verbena officinalis*	O	O					O			
herb	Violaceae	*Viola betonicifolia*	Native Violet	*Viola betonicifolia*		O	O	R						
herb	Onagraceae	*Epilobium billardierianum* subsp. *cinereum*		*Epilobium cinereum*	O						O			

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herbs	Fabaceae, Subfamily Faboideae	* *Lupinus* spp.		* *Lupinus* sp.	R									R
shrub	Apocynaceae	* *Nerium oleander*	Oleander	* *Nerium oleander*		R			R					
shrub	Araliaceae	*Polyscias sambucifolia*	Elderberry ash	*Polyscias sambucifolia*	O	O	O	O	R					
shrub	Asparagaceae	* *Asparagus aethiopicus*	Asparagus 'Fern', Sprengeri Fern	* *Asparagus sprengeri*	R	R	R	R						
shrub	Asteraceae	* *Chrysanthemoides monilifera*	Bitou Bush, Boneseed	* *Chrysanthemoides moniliferum*	X	O		X					X	
shrub	Asteraceae	*Cassinia arcuata*	Sifton Bush, Chinese Shrub	*Cassinia arcuata*	X	X	R	O		X				
shrub	Asteraceae	*Olearia microphylla*		*Olearia microphylla*	O	X	X	X						
shrub	Asteraceae	*Ozothamnus diosmifolius*		* *Helichrysum diosmifolium*	X	X	O	X						
shrub	Caprifoliaceae	* *Abelia x grandiflora*	Abelia chinensis x Abelia uniflora	* *Abelia x grandiflora*		R	micro-environment not recorded							
shrub	Celastraceae	*Maytenus silvestris*	Orange Bark	*Maytenus cunninghamii*	X	X	O	X						
shrub	Ericaceae subfamily Stephelioideae	*Leucopogon lanceolatus* var. *lanceolatus*		*Leucopogon lanceolatus* var. *lanceolatus*		O					O			
shrub	Ericaceae subfamily Stephelioideae	*Monotoca scoparia*		*Monotoca scoparia*	R			R						
shrub	Euphorbiaceae	* *Ricinus communis*	Castor Oil Plant	* *Ricinus communis*	R	R					R			
shrub	Euphorbiaceae	*Homalanthus stillingiifolius*		*Omalanthus stillingiifolius*	R	R	R	R						
shrub	Fabaceae subfamily Caesalpiniodeae	* *Senna pendula* var. *glabrata*		* *Cassia coluteoides*	R	R					R			R
shrub	Fabaceae subfamily Mimosoideae	* *Acacia saligna*	Golden Wreath Wattle	* *Acacia saligna*	X			O	O				X	
shrub	Fabaceae subfamily Mimosoideae	*Acacia falcata*		*Acacia falcata*	X	X	O	X	O	X	O		O	O
shrub	Fabaceae subfamily Mimosoideae	*Acacia longifolia subsp. longifolia*	Sydney Golden Wattle	*Acacia longifolia var. longifolia*	X	X	O	X	X	O	O		O	O
shrub	Fabaceae subfamily Mimosoideae	*Acacia myrtifolia*	Myrtle Wattle	*Acacia myrtifolia*	O								O	

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shrub	Fabaceae subfamily Mimosoideae	*Acacia stricta*	Straight Wattle	*Acacia stricta*		R		R						
shrub	Fabaceae subfamily Mimosoideae	*Acacia suaveolens*	Sweet Wattle	*Acacia suaveolens*	R			R						
shrub	Fabaceae subfamily Mimosoideae	*Acacia ulicifolia*	Prickly Moses	*Acacia ulicifolia*	O	O	O	O		O			O	
shrub	Fabaceae, Subfamily Faboideae	* *Genista linifolia*	Flaxleaf Broom	* *Teline linifolia*	O									O
shrub	Fabaceae, Subfamily Faboideae	* *Genista monspessulana*	Montpellier Broom	* *Teline monspessulana*	O	O			O	O				O
shrub	Fabaceae, Subfamily Faboideae	* *Tephrosia grandiflora*		* *Tephrosia grandiflora*	R			R			R			
shrub	Fabaceae, Subfamily Faboideae	* *Ulex europaeus*	Furze, Gorse	* *Ulex europaeus*	O								O	
shrub	Fabaceae, Subfamily Faboideae	*Daviesia ulicifolia*	Gorse Bitter Pea	*Daviesia ulicifolia*	O	X	O	O	O	R				R
shrub	Fabaceae, Subfamily Faboideae	*Dillwynia juniperina*		*Dillwynia juniperina*	X	X	O	X	X	O				
shrub	Fabaceae, Subfamily Faboideae	*Hovea longifolia*	Rusty Pods	*Hovea longifolia*		O					O			
shrub	Fabaceae, Subfamily Faboideae	*Indigofera australis*	Australian Indigo, Duwabili (D'harawal)	*Indigofera australis*		O	O	O	O					O
shrub	Fabaceae, Subfamily Faboideae	*Podolobium ilicifolium*	Prickly Shaggy Pea	*Oxylobium ilicifolium*	O			O						
shrub	Fabaceae, Subfamily Faboideae	*Pultenaea villosa*	Hairy Bush-pea	*Pultenaea villosa*	X	X	R	O	O	X			O	O
shrub	Fabaceae, Subfamily Faboideae	*Viminaria juncea*	Native Broom	*Viminaria juncea*	R						R			

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shrub	Goodeniaceae	*Goodenia ovata*	Hop Goodenia	*Goodenia ovata*		R					R			
shrub	Loranthaceae	*Amyema gaudichaudii*		*Amyema gaudichaudii*	O	O	O	O						
shrub	Loranthaceae	*Dendrophthoe vitellina*		*Dendrophthoe vitellina*	O	O		O			O			
shrub	Loranthaceae	*Muellerina eucalyptoides*		*Muellerina eucalyptoides*	O	O	O	O						
shrub	Malaceae	* *Cotoneaster* spp.		* *Cotoneaster* sp.	R	R		R					R	
shrub	Malaceae	* *Rhaphiolepis indica*	Indian Hawthorn	* *Raphiolepis indica*	R								R	
shrub	Myrtaceae	*Callistemon citrinus*	Crimson bottlebrush	*Callistemon citrinus*	R		micro-environment not recorded							
shrub	Myrtaceae	*Callistemon linearis*	Narrow-leaved Bottlebrush	*Callistemon linearis*	O	O		O	O					
shrub	Myrtaceae	*Callistemon pinifolius*	Pine-leaved Bottlebrush	*Callistemon pinifolius*	O	O		O	O					
shrub	Myrtaceae	*Callistemon rigidus*	Stiff Bottlebrush	*Callistemon rigidus*	O	O		O	O					
shrub	Myrtaceae	*Callistemon salignus*	Willow Bottlebrush	*Callistemon salignus*	R	O	R	R			O			
shrub	Myrtaceae	*Kunzea ambigua*	Tick Bush	*Kunzea ambigua*	X	O				X				
shrub	Myrtaceae	*Leptospermum polygalifolium* subsp. *polygalifolium*	Tantoon	*Leptospermum flavescens*	O	O					O			
shrub	Myrtaceae	*Leptospermum trinervium*	Flaky-barked Tea-tree	*Leptospermum attenuatum*		O			X		O		X	
shrub	Myrtaceae	*Melaleuca armillaris*	Bracelet Honey-Myrtle	* *Melaleuca armillaris*	O	O			O					
shrub	Myrtaceae	*Melaleuca decora*		*Melaleuca decora*	X	X	X	X	O	O	O			
shrub	Myrtaceae	*Melaleuca ericifolia*	Swamp Paperbark	*Melaleuca ericifolia*		O					O			
shrub	Myrtaceae	*Melaleuca erubescens*		*Melaleuca erubescens*	O	O		O						
shrub	Myrtaceae	*Melaleuca hypericifolia*	Hillock Bush	*Melaleuca hypericifolia*	R		micro-environment not recorded							
shrub	Myrtaceae	*Melaleuca nodosa*	Prickly-leaved Paperbark	*Melaleuca nodosa*	X	X	X	X	X	O	O			
shrub	Myrtaceae	*Melaleuca thymifolia*	Thyme Honey-myrtle	*Melaleuca thymifolia*	X	O		O	O		X			
shrub	Nyctaginaceae	* *Bougainvillea* spp.		* *Bougainvillea* sp	R	R			R				R	
shrub	Ochnaceae	* *Ochna serrulata*	Mickey Mouse Plant	* *Ochna serrulata*	O	O	O	O						

Growth form	Current Family	Current Name	Common Name	Price's species names	Cemetery	Duck River	Low woodland, Duck River	Ti-tree & eucalypt scrub	Grasslands	Exposed soils & subsoils	Drainage lines, permanent water edges	Permanent & transient sheets of water	Graves, RW cemetery	Dumped soil, road & track edges
shrub	Oleaceae	* *Ligustrum sinense*	Small Leaved Privet	* *Ligustrum sinense*	R	O	R	R			O			
shrub	Oleaceae	*Notelaea ovata*		*Notelea ovata*		R		R						
shrub	Phyllanthaceae	*Breynia oblongifolia*	Coffee Bush	*Breynia oblongifolia*	O	X	X	O						
shrub	Phyllanthaceae	*Phyllanthus gunnii*	Scrubby Spurge	*Phyllanthus gasstroemii*		X	X	X						
shrub	Pittosporaceae	*Bursaria spinosa*	Blackthorn, Sweet Bursaria, Kurwan (D'harawal)	*Bursaria spinosa*	X	X	O	X	O					
shrub	Pittosporaceae	*Pittosporum revolutum*	Rough fruit Pittosporum	*Pittosporum revolutum*	O	O	O	O						
shrub	Polygalaceae	* *Polygala myrtifolia*		* *Polygala myrtifolia*	R								R	
shrub	Polygalaceae	* *Polygala virgata*		* *Polygala virgata*	O						O		O	
shrub	Proteaceae	*Banksia oblongifolia*	Fern-leaved Banksia	*Banksia aspleniifolia*	R			R						
shrub	Proteaceae	*Banksia spinulosa* var. *spinulosa*	Hairpin Banksia	*Banksia spinulosa*	X			X						
shrub	Proteaceae	*Hakea sericea*	Needlebush	*Hakea sericea*	X	R		O		X	R			
shrub	Proteaceae	*Isopogon anemonifolius*	Broad-leaf Drumsticks	*Isopogon anemonifolius*	R			R						
shrub	Proteaceae	*Persoonia laurina*	Laurel Geebung	*Persoonia laurina*	R			R						
shrub	Proteaceae	*Persoonia linearis*	Narrow-leaved Geebung	*Persoonia linearis*		R					R			
shrub	Rhamnaceae	*Pomaderris ferruginea*	Rusty Pomaderris	*Pomaderris ferruginea*	unclear entry	R		R			R			
shrub	Rhamnaceae	*Pomaderris lanigera*	Woolly Pomaderris	*Pomaderris lanigera*		R					R			
shrub	Rhamnaceae	*Pomaderris prunifolia*	Plum-leaf Pomaderris	*Pomaderris prunifolia*	R			R						
shrub	Rosaceae	* *Photinia glabra*	Japanese Photinia	* *Photinia glabra*		R				R	R			
shrub	Rosaceae	* *Rosa* spp.		* *Rosa spp.*	O	R					R		O	R
shrub	Rosaceae	* *Rubus laciniatus*	Cut-leaf Blackberry	* *Rubus vulgaris*	O	O		R			O		O	
shrub	Rosaceae	* *Spiraea cantoniensis*	May Bush	* *Spiraea cantoniensis*	R	R							R	R
shrub	Rutaceae	*Asterolasia correifolia*		*Asterolasia correifolia*		R					R			
shrub	Rutaceae	*Correa reflexa* var. *reflexa*	Native Fuchsia	*Correa reflexa* var. *reflexa*		O	O	O		R				
shrub	Rutaceae	*Zieria smithii*		*Zieria smithii*		O		R			O			
shrub	Santalaceae	*Exocarpos cupressiformis*	Cherry Ballart, Native Cherry	*Exocarpos cupressiformis*	R	O	R	O						
shrub	Santalaceae	*Exocarpos strictus*	Pale-fruit Ballart, Dwarf Cherry	*Exocarpos strictus*		R		R						

Growth form	**Current Family**	**Current Name**	**Common Name**	**Price's species names**	**Cemetery**	**Duck River**	**Low woodland, Duck River**	**Ti-tree & eucalypt scrub**	**Grasslands**	**Exposed soils & subsoils**	**Drainage lines, permanent water edges**	**Permanent & transient sheets of water**	**Graves, RW cemetery**	**Dumped soil, road & track edges**
shrub	Sapindaceae	*Dodonaea triquetra*	Large-leaf Hop Bush	*Dodonaea triquetra*		X	X	X						
shrub	Solanaceae	* *Cestrum aurantiacum*	Orange Cestrum	* *Cestrum aurantiacum*	R	R	R				R			
shrub	Solanaceae	* *Cestrum parqui*	Green Cestrum, Green Poisonberry	* *Cestrum parqui*	site not recorded		R				R			
shrub	Solanaceae	* *Lycium ferocissimum*	African Boxthorn	* *Lycium ferocissimum*		R				R				
shrub	Solanaceae	* *Solanum mauritianum*	Wild Tobacco Bush	* *Solanum mauritianum*		R	R				R			
shrub	Solanaceae	* *Solanum pseudocapsicum*	Madeira Winter Cherry	* *Solanum pseudocapsicum*		O	R	O						
shrub	Sterculiaceae	*Rulingia dasyphylla*	Kerrawang	*Rulingia pannosa*	R	X	X	R						
shrub	Thymelaeaceae	*Pimelea linifolia*	Slender Rice Flower	*Pimelea linifolia*	R	X	O	X	X					
shrub	Verbenaceae	* *Lantana camara*	Lantana	* *Lantana camara*	R	O	O							
shrub	Verbenaceae	* *Lantana montevidensis*	Trailing Lantana	* *Lantana montevidensis*	R								R	
shrub	Fabaceae subfamily Mimosoideae	* *Acacia podalyriifolia*	Queensland Silver Wattle	* *Acacia podalyriifolia*	R									R
shrub	Fabaceae subfamily Mimosoideae	* *Acacia pycnantha*	Golden Wattle	* *Acacia pycnantha*	O				O				O	
shrub	Fabaceae subfamily Mimosoideae	*Acacia longissima*	Long-leaf Wattle	*Acacia longissima*	R					R				
shrub	Fabaceae subfamily Mimosoideae	*Acacia pubescens*	Downy Wattle	*Acacia pubescens*	O	X	O	X		R				
shrub	Myoporaceae	*Myoporum insulare*	Boobialla	*Myoporum insulare*		R	R				R			
shrub	Myrsinaceae	*Myrsine variabilis*		*Rapanea variabilis*	O	O	O	O						
shrub	Zamiaceae	*Macrozamia spiralis*		*Macrozamia spiralis*	O	O	O	O	O					
shrub, vulnerable	Ericaceae subfamily Stephelioideae	*Epacris purpurascens* var. *purpurascens*		*Epacris purpurascens* var. *purpurascens*	O			O						
subshrub	Apiaceae	*Platysace ericoides*		*Platysace ericoides*	X			X	X				X	
subshrub	Dilleniaceae	*Hibbertia aspera*	Rough Guinea Flower	*Hibbertia aspera*	O	O		O	O	O				O
subshrub	Dilleniaceae	*Hibbertia diffusa*	Wedge Guinea Flower	*Hibbertia diffusa*		R		R						
subshrub	Dilleniaceae	*Hibbertia pedunculata*		*Hibbertia pedunculata*	O	O		O	O					

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subshrub	Ericaceae subfamily Styphelioideae	*Astroloma humifusum*	Native Cranberry	*Astroloma humifusum*	X	O				X				
subshrub	Ericaceae subfamily Styphelioideae	*Leucopogon juniperinus*	Prickly Beard-heath	*Leucopogon juniperinus*	O	O	O	O						
subshrub	Ericaceae subfamily Styphelioideae	*Lissanthe strigosa*	Peach Heath	*Lissanthe strigosa*	X	X		X	X					
subshrub	Fabaceae subfamily Mimosoideae	*Acacia brownii*	Heath Wattle	*Acacia brownii*	O	O	O	O		O				
subshrub	Fabaceae, Subfamily Faboideae	*Bossiaea buxifolia*		*Bossiaea buxifolia*		O			O					
subshrub	Fabaceae, Subfamily Faboideae	*Bossiaea prostrata*		*Bossiaea prostrata*	O	O		O	O					
subshrub	Fabaceae, Subfamily Faboideae	*Chorizema parviflorum*	Eastern Flame Pea	*Chorizema parviflorum*	O	O		O	O					
subshrub	Fabaceae, Subfamily Faboideae	*Dillwynia parvifolia*		*Dillwynia parvifolia var. parvifolia*	X		X	X	O					
subshrub	Fabaceae, Subfamily Faboideae	*Gompholobium glabratum*	Dainty Wedge Pea	*Gompholobium glabratum*		O			O					
subshrub	Fabaceae, Subfamily Faboideae	*Gompholobium minus*	Dwarf Wedge Pea	*Gompholobium minus*	R			R						
subshrub	Fabaceae, Subfamily Faboideae	*Mirbelia rubiifolia*	Heathy Mirbelia	*Mirbelia rubiifolia*	R						R			
subshrub	Fabaceae, Subfamily Faboideae	*Pultenaea retusa*	Notched Bush-pea	*Pultenaea retusa*	R	R			R					R
subshrub	Geraniaceae	* *Pelargonium asperum*	Rose Geranium	* *Pelargonium aspera*	R								R	
subshrub	Geraniaceae	* *Pelargonium x domesticum*	Pelargonium	* *Pelargonium domesticum*	R	R							R	R
subshrub	Haloragaceae	*Gonocarpus longifolius*		*Haloragis villosa*	R				R					
subshrub	Malvaceae	* *Sida rhombifolia*	Paddy's Lucerne	* *Sida rhombifolia*	X	X	O	O			O			O

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subshrub	Myoporaceae	*Eremophila debilis*	Winter Apple, Amula	*Myoporum debile*		O	O	O						
subshrub	Picrodendraceae	*Micrantheum ericoides*		*Micrantheum ericoides*	X			X						
subshrub	Pittosporaceae	*Rhytidosporum procumbens*		*Marianthus procumbens*	R		micro-environment not recorded							
subshrub	Rubiaceae	*Opercularia aspera*	Coarse Stinkweed	*Opercularia aspera*		R		R						
subshrub	Rubiaceae	*Opercularia varia*	Variable Stinkweed	*Opercularia varia*		R					R			
subshrub	Rubiaceae	*Pomax umbellata*		*Pomax umbellata*	X		X							
subshrub	Rutaceae	*Boronia polygalifolia*	Dwarf Boronia	*Boronia polygalifolia*		O	O							
subshrub	Solanaceae	* *Solanum linnaeanum*	Apple of Sodom	* *Solanum sedomaeum*		R								R
subshrub	Sterculiaceae	*Lasiopetalum parviflorum*		*Lasiopetalum parviflorum*	R	X	X	R						
succulent	Agavaceae	* *Agave americana*	Century plant	* *Agave americana*	R								R	
succulent	Asphodelaceae	* *Aloe* spp.		* *Aloe* sp.	R	R				R				
succulent	Cactaceae	* *Opuntia stricta*	Prickly Pear, Smooth Pest Pear	* *Opuntia stricta*		R					R			R
tree	Amygdalaceae	* *Prunus domestica*	Plums	* *Prunus domestica*		R					R			
tree	Amygdalaceae	* *Prunus persica*	Peach, Nectarine	* *Prunus persica*		R					R			
tree	Araucariaceae	* *Araucaria bidwillii*	Bunya Pine	* *Araucaria bidwillii*	R								R	
tree	Araucariaceae	* *Araucaria columnaris*	Cook Pine	* *Araucaria columnaris*	R		micro-environment not recorded							
tree	Arecaceae	* *Phoenix canariensis*	Canary Island Date Palm	* *Phoenix canariensis*	R			R			R		R	
tree	Casuarinaceae	*Allocasuarina littoralis*	Black She-oak	*Casuarina littoralis*	R			R						
tree	Casuarinaceae	*Allocasuarina torulosa*	Forest Oak	*Casuarina torulosa*	R	R	R	R						R
tree	Casuarinaceae	*Casuarina glauca*	Swamp Oak	*Casuarina glauca*	X	O					X			
tree	Fabaceae subfamily Mimosoideae	* *Acacia baileyana*	Cootamundra Wattle	* *Acacia baileyana*	R	R		R						R
tree	Fabaceae subfamily Mimosoideae	*Acacia binervia*	Coast Myall	*Acacia glaucescens*	R	R	R	R	R		R			R
tree	Fabaceae subfamily Mimosoideae	*Acacia decurrens*	Black Wattle, Green Wattle	*Acacia decurrens*	O	X	O	O	O	O	O		O	O

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tree	Fabaceae subfamily Mimosoideae	*Acacia parramattensis*	Sydney Green Wattle	*Acacia parramattensis*	X	X	O	X	X		O		O	O
tree	Fabaceae subfamily Mimosoideae	* *Erythrina crista-galli*	Cockspur Coral Tree	*Erythina* sp.	R	R					R		R	
tree	Fabaceae, Subfamily Faboideae	* *Robinia pseudoacacia*	Black Locust	* *Robinia pseudoacacia*	X								X	
tree	Fabaceae, Subfamily Faboideae	*Jacksonia scoparia*	Winged Broom-pea	*Jacksonia scoparia*		R	R		R					
tree	Lauraceae	* *Cinnamomum camphora*	Camphor Laurel	* *Cinnamomum camphora*	O	R			O		O		O	O
tree	Lythraceae	* *Lagerstroemia indica*	Crepe Myrtle	* *Lagerstroemia indica*	R	R							R	R
tree	Moraceae	* *Morus alba*	White Mulberry	* *Morus alba*		R		R			R			
tree	Moraceae	* *Morus nigra*	Black Mulberry	* *Morus nigra*		R		R						
tree	Myrtaceae	* *Eucalyptus cinerea*	Argyle Apple	*Eucalyptus cinerea*	R	R	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus cladocalyx*	Sugar Gum	*Eucalyptus cladocalyx*	O	R	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus globulus Labill.* var. *globulus*	Tasmanian Blue Gum	*Eucalyptus globulus ssp. globulus*	R		micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus globulus* subsp. *pseudoglobulus*	Victorian Eurabbie	*Eucalyptus globulus* ssp. *st johnii*	O	O	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus grandis*	Flooded Gum	*Eucalyptus grandis*	O		micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus leucoxylon*	Yellow Gum	*Eucalyptus leucoxylon*		R	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus maidenii*	Maiden's Gum	* *Eucalyptus globulus* ssp. *maidenii*		R	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus melanophloia*	Silver-leaved Ironbark	*Eucalyptus melanophloia*		R	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus melliodora*	Yellow Box	*Eucalyptus melliodora*	O	O							O	

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tree	Myrtaceae	* *Eucalyptus microcorys*	Tallowwood	*Eucalyptus microcorys*	X	X							X	X
tree	Myrtaceae	* *Eucalyptus nicholii*	Narrow-leaved Black Peppermint	*Eucalyptus nicholii*	O	O	micro-environment not recorded							
tree	Myrtaceae	* *Eucalyptus saligna*	Sydney Blue Gum	* *Eucalyptus saligna*	O	O			O				O	
tree	Myrtaceae	* *Eucalyptus smithii*	Ironbark Peppermint, Gully Gum	*Eucalyptus smithii*	R		micro-environment not recorded							
tree	Myrtaceae	* *Tristania conferta*	Brush Box	* *Tristania conferta*	O								O	
tree	Myrtaceae	*Angophora bakeri*	Narrow-leaved Apple	*Angophora bakeri*	X			O		O	X		O	
tree	Myrtaceae	*Angophora costata*	Sydney Red Gum, Smooth-barked Apple	*Angophora costata*	O	O	micro-environment not recorded							
tree	Myrtaceae	*Angophora floribunda*	Rough-barked Apple	*Angophora floribunda*	R	X	R	R	R	O	X			
tree	Myrtaceae	*Corymbia citriodora*	Lemon-scented Gum	* *Eucalyptus citriodora*	X	O		O		O			X	O
tree	Myrtaceae	*Corymbia gummifera*	Red Bloodwood	*Eucalyptus gummifera*	R		micro-environment not recorded							
tree	Myrtaceae	*Corymbia maculata*	Spotted Gum	*Eucalyptus maculata*	X	O	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus acaciiformis*	Wattle-leaved Peppermint	*Eucalyptus acaciaformis*	O	O	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus amplifolia*	Cabbage Gum	*Eucalyptus amplifolia*		O	R	R		O	O			
tree	Myrtaceae	*Eucalyptus botryoides*	Bangalay	*Eucalyptus botryoides*	O	O	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus crebra*	Narrow-leaved Ironbark, Muggago (D'harawal)	*Eucalyptus crebra*		R	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus elata*	River Peppermint	*Eucalyptus elata*		R	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus eugenioides*	Thin-leaved Stringybark	*Eucalyptus eugenioides*	X	X	O	O	O	O	O		O	O

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tree	Myrtaceae	*Eucalyptus eximea*	Yellow Bloodwood	*Eucalyptus eximea*	R		micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus fibrosa*	Red Ironbark	*Eucalyptus fibrosa*	X	X	X	X			O			
tree	Myrtaceae	*Eucalyptus globoidea*	White Stringybark	*Eucalyptus globoidea*	X	O	O	X		O	O		O	
tree	Myrtaceae	*Eucalyptus longifolia*	Woollybutt	*Eucalyptus longifolia*	X	X	X	X					O	
tree	Myrtaceae	*Eucalyptus moluccana*	Grey Box, Terriyergro (D'harawal)	*Eucalyptus moluccana*	R	X	X	X			O			
tree	Myrtaceae	*Eucalyptus paniculata*	Grey Ironbark	*Eucalyptus paniculata*	O	R		O					O	
tree	Myrtaceae	*Eucalyptus parramattensis*	Parramatta Red Gum	*Eucalyptus parramattensis*	R			R					R	
tree	Myrtaceae	*Eucalyptus pilularis*	Blackbutt	*Eucalyptus pilularis*	R	R	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus punctata*	Grey Gum	*Eucalyptus punctata*	R	O	O	O					R	
tree	Myrtaceae	*Eucalyptus resinifera*	Red Mahogany	*Eucalyptus resinifera*	X	X	X	X			X			
tree	Myrtaceae	*Eucalyptus robusta*	Swamp Mahogany	*Eucalyptus robusta*	X	X	micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus sclerophylla*	Hard-leaved Scribbly Gum	*Eucalyptus sclerophylla*	O			O						O
tree	Myrtaceae	*Eucalyptus sideroxylon*	Mugga Ironbark	*Eucalyptus sideroxylon*	O	O		R						
tree	Myrtaceae	*Eucalyptus* spp. - a *scribbly gum*		*Eucalyptus* sp. - a *scribbly gum*	R		micro-environment not recorded							
tree	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum, Buringoa (D'harawal	*Eucalyptus tereticornis*	O	R	R	R	O				O	O
tree	Myrtaceae	*Eucalyptus viminalis*	Ribbon Gum	*Eucalyptus viminalis*		R	micro-environment not recorded							
tree	Myrtaceae	*Melaleuca linariifolia*	Flax-leaved Paperbark, Budjur (Gadigal)	*Melaleuca linariifolia*	O	O					O			
tree	Myrtaceae	*Melaleuca quinquenervia*	Broad-leaved Paperbark	*Melaleuca quinquenervia*	O				O					
tree	Myrtaceae	*Melaleuca styphelioides*	Prickly-leaved Tea Tree	*Melaleuca styphelioides*	O	X	X	X	O		O			

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tree	Myrtaceae	*Syncarpia glomulifera*	Turpentine	*Syncarpia glomulifera*	X	R	X	X	O					
tree	Oleaceae	*Notelaea longifolia*	Large Mock-olive	*Notelea longifolia*	X	X	O	X	O					
tree	Phyllanthaceae	*Glochidion ferdinandi*	Cheese Tree	*Glochidion ferdinandi*		R	R							
tree	Pinaceae	* *Pinus halepensis*	Aleppo pine	* *Pinus halepensis*	O								O	
tree	Pinaceae	* *Pinus pinaster*	Cluster Pine	* *Pinus pinaster*	O								O	
tree	Pinaceae	* *Pinus pinea*	Stone Pine	* *Pinus pinea*	O								O	
tree	Pinaceae	* *Pinus radiata*	Radiata Pine	* *Pinus radiata*	O								O	
tree	Pittosporaceae	*Pittosporum undulatum*	Sweet Pittosporum	*Pittosporum undulatum*	O	O	O	O						
tree	Salicaceae	* *Salix babylonica*	Weeping Willow	* *Salix babylonica*		O					O			
tree	Sterculiaceae	*Brachychiton populneus*	Kurrajong	*Brachychiton populneum*		R	R	R						
tree	Oleaceae	* *Ligustrum lucidum*	Large Leaved Privet	* *Ligustrum lucidum*	R	R	R	R						
				Number of exotics	185	214	27	51	81	17	113	9	53	102
				Number of natives	211	253	107	179	128	41	82	7	26	35
				Total species	396	467	134	230	209	58	195	16	79	137

Appendix 2

The Vegetation of Duck River and
Rookwood Cemetery, Auburn
(with a list of species)

G.A. Price

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II. Landform, Geology and Soils 1
III. Climate 2
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  (a) The Creeks, waterholes, seasonally flooded lands and drainage lines 3
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Appendix II List of species collected only at Rookwood
Bibliography

Map I (Included in text) Location of sample areas
Map II (at rear) Duck and Haslems Creeks
Map III Duck River sample area (at rear)
Map IV Rookwood sample area (at rear)

The argument: The Auburn area carries the remnants of a much disturbed flora representative of that normally found in the wetter parts of the Wianamatta shales of the Cumberland Basin but there is also the remnants of a sandstone flora, particularly at Rookwood. The original type of vegetation was probably a tall woodland or dry schlerophyll forest in which the dominant trees were those of the drier parts of the Cumberland Basin (an Eucalyptus moluccana-E.fibrosa ssp. fibrosa) Association) but a number of the subordinant tree species and many of the understorey plants were species of moister environments. There are no longer any stands of the original tall woodlands and the disturbed vegetation has been shaped largely by man and fire into grasslands (dominated by either native or exotic associations of grasses and herbs), ti-tree and eucalypt scrub (with Kunzea scrub a variant on exposed sub-soils) but in one area the scrub has evolved into a low woodland.

The Vegetation of Duck River and
Rookwood Cemetery, Auburn

G.A.Price

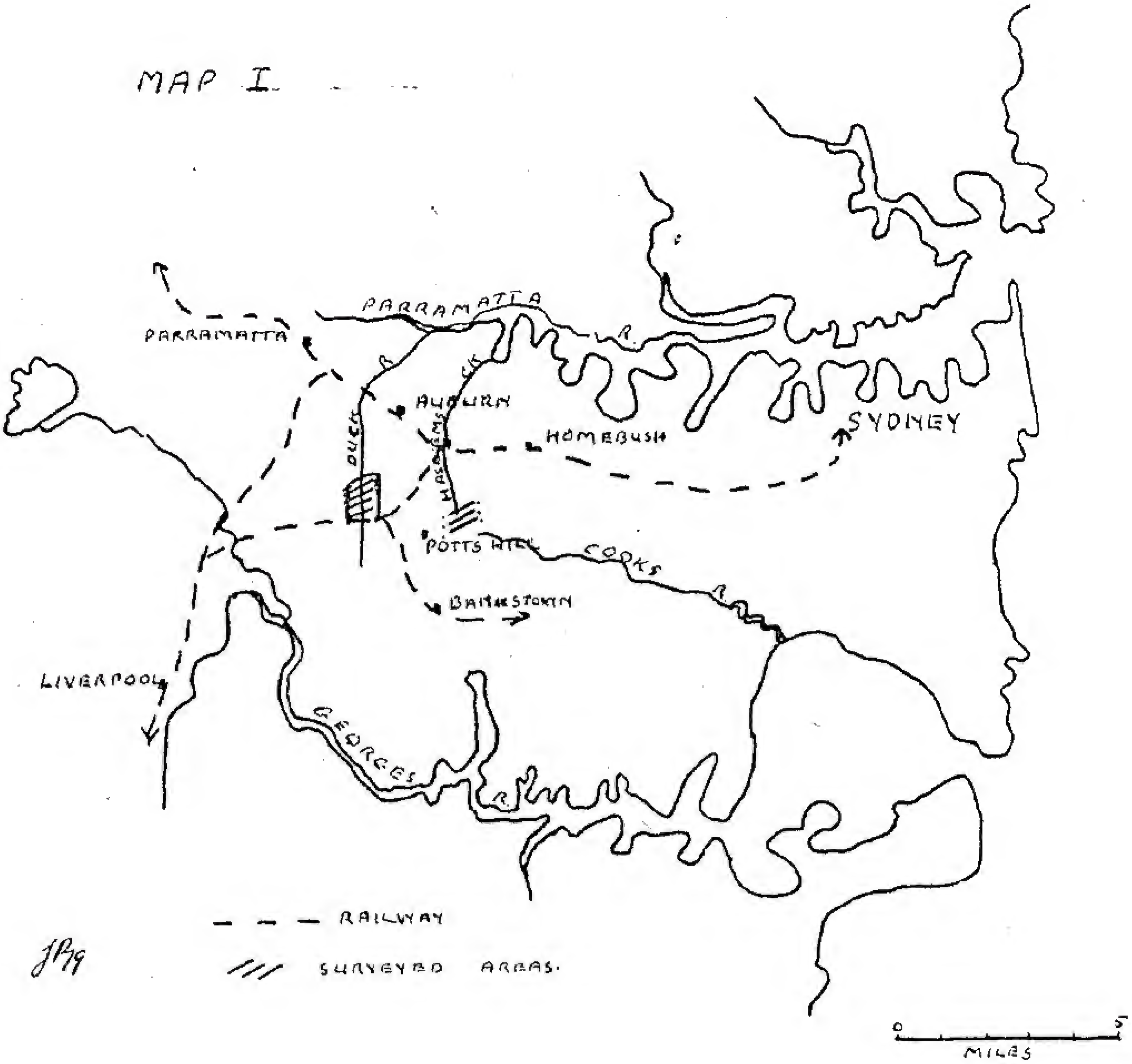
I. Location

The parts of the Rookwood Cemetery and the Duck River which have been surveyed are in the mid -western suburbs of Sydney 12-14 miles W.S.W. of the city (see Map I). Both are part of the southwestern portion of the Parramatta River Basin butthe southern end of the Rookwood Cemetery extends over the divide between Haslem's and the Freshwater Creeks into the upper reaches of the Cooks River.

II. Landform, Geology and Soils

The Duck River and Haslem's Creek basins (see map II) form a V-shaped wedge of country that pivots in the south east on the sandstones exposed in the high country about Potts Hill by the warping and differential ersoion that has helped form the Cumberland Basin. Outliers of sandstone-like rocks occur north of Potts Hill at such places as Phillips Hill (not seen) and the Presbyterian burial ground near Georges Avenue (a silicified siltstone). The Duck River has also cut down into a quite large stratum of sandstone that underlies and extends some distance beyond the survey area there. But none of the sandstones north of Potts Hill is massive, each apparently having a quite high clay content, and none has any obvious effect on the shape of the land. The dominant bedrock is the soft, easily eroded shales of the Wianamatta Series that are so deeply weathered that they are exposed only in railway cuttings (Rookwood, Regents Park, Chullora) and so little above base level that the land is nearly flat or gently undulating.

Both basins are poorly defined by gentle undulations little more than forty metres above sea level. The broad, almost flat plain rising gradually to the east and west and imperceptibly to the low undulations that still cut across the creeks' courses is largest on Duck River and encompasses the whole of the survey area there. The area in the Rookwood cemetery and the old State Hospital grounds is nearer to or onthe southern and eastern watershed of Haslem's creek so the country is more undulating. However, fingers of flat land extend well upstream into the cemetery from Lidcombe and are broader in the Carnarvon Golf Course (once part of the Hopstival). The Duck River seems to have had a permanent flow these past three years though often it has been little more than a trickle of factory effluent and street drainage though that is pure enough these days to support freshwater fish and tortoise and the breeding of ducks on the deeper, broader reaches. Nonetheless, 'the river' above its tidal basin is simply a stormwater channel for all that its natural banks have been kept in Auburn and Granville. Its level can change abruptly and flooding may occur below Chisolm Road after heavy storms once the catchment has become saturated. Haslem's Creek is a series of stormwater channels that flow after rain, even the most


MAP I
PARRAMATTA R.
PARRAMATTA
DUCK R
AUBURN
HASLEMS CK
HOMEBUSH
SYDNEY
POTTS HILL
COOKS R.
BANKSTOWN
LIVERPOOL
GEORGES R.
RAILWAY
SURVEYED AREAS.
0
5
MILES

ephemeral gullies in the State Hospital grounds and the Cemetery having been bricked.

Soils everywhere seem to be deep, as much as up to six to eight feet on even the Duck River sandstones, and seem always to be underlain by much decaying rock. To the eye, topsoils seem alike whatever the baserock and are a grey, vertically jointed, podsol-like 'A' horizon up to some 12-18 inches deep that protects a softer, more easily erodable subsoil. Subsoils seem more variable in colour and texture but seem always to be clays - deep, tough, elastic red clays at 296 Park Road and on the northern slopes of Freshwater Creek, a yellowish-white and somewhat more crumbly clay once much valued by local tile and pipeworks on the Duck River sandstones. Since allthe soils seem to have a high clay content they are prone to crack widely and deeply in exposed places in dry weather, many of these fractures apparently persisting for years (Duck River, 296 Park Road) and sometimes become accentuated by erosion to give a peculiar raised and block-like appearance to the surface. In wet seasons all soils become saturated and most water runs off the surface rather than percolating into the subsoil. Fertility is moderate though I have not had any samples analysed. Yet, for all this apparent uniformity in the soils the remnants of a sandstone flora occur in the headwaters of Haslem's Creek and at Potts Hill but are less well represented on the Duck River. However, most of the species collected are those that are normally found on Wianamatta shales.

III. Climate

The average annual rainfall and temperature figures (see page 3) are those of an area with mild wet winters and warm wet summers and put the sample area towards the milder, wetter end of the specturm of climatic change that occurs from east to west in the Sydney Basin. Rainfall is sufficiently high for there once to have been a 'tall woodland' or 'forest' yet sufficiently variable, given the nature of the soils, for tree species from the drier west such as Eucalyptus moluccana, E.eugenioides, E. parramattensis and E. longifolia to mingle with others from wetter areas such as E.resinifera and Syncarpia glomulifera. Shrub species also range from plants such as Kunzea ambigua, Pultenaea villosa that grow well only in open, somewhat exposed situations to others such as Glochidion ferdinandi, Breynia oblongifolia and Notolaea longifolia which are normally plants of wet, shaded forests.

However, average figures of the sort given above are often less important for plants than the extremes they mask. Even over the past ~~three~~ five years rainfall has been sufficiently variable for the totals for the years to be roughly 'average' though the soils have been waterlogged for months on end (as in the winter, spring, and early summer of 1976) and then to have gradually dried out and cracked deeply (late summer, early autumn of 1977). Exposure to sun and wind, particularly to the hot dry north-westerlies in summer and cold dry south westerlies in winter can compound these problems of soil moisture and the stress that they can cause in plants. In the spring of 1977, for example, soils were deeply c cracked and even the toughest of herbs and grasses were beginning to fail where the aspect was north westerly one without shelter. Yet scarcely fifty yards away in sheltered woodland soft species such as the maiden hair fern (*Adiantum aethiopicum*) were growing well in a topsoil which was still moist. Probably similar variations in temperature extremes can occur. Frost, for example, seems only to occur in open grasslands at Duck River and trees and shrubs there provide a great deal of shelter from chill southerlies in winter.

The survey was made during a cycle of wetter than average years and it may be that during droughts some of the plants adapted to moister environments might fail as the one colony of *Pomaderris ferruginea* on Duck River almost did during the dry spring of 1977. However, there would probably always be moister, more sheltered niches in which said species might survive or re-establish. Of course, it may be that at least some of the aberrant distributions given in the species list owe little or no thing to changes in rainfall and are due simply to the disturbed ecology of the bushland areas about Sydney and the changes in the habits of migratory birds and so on that this has caused.

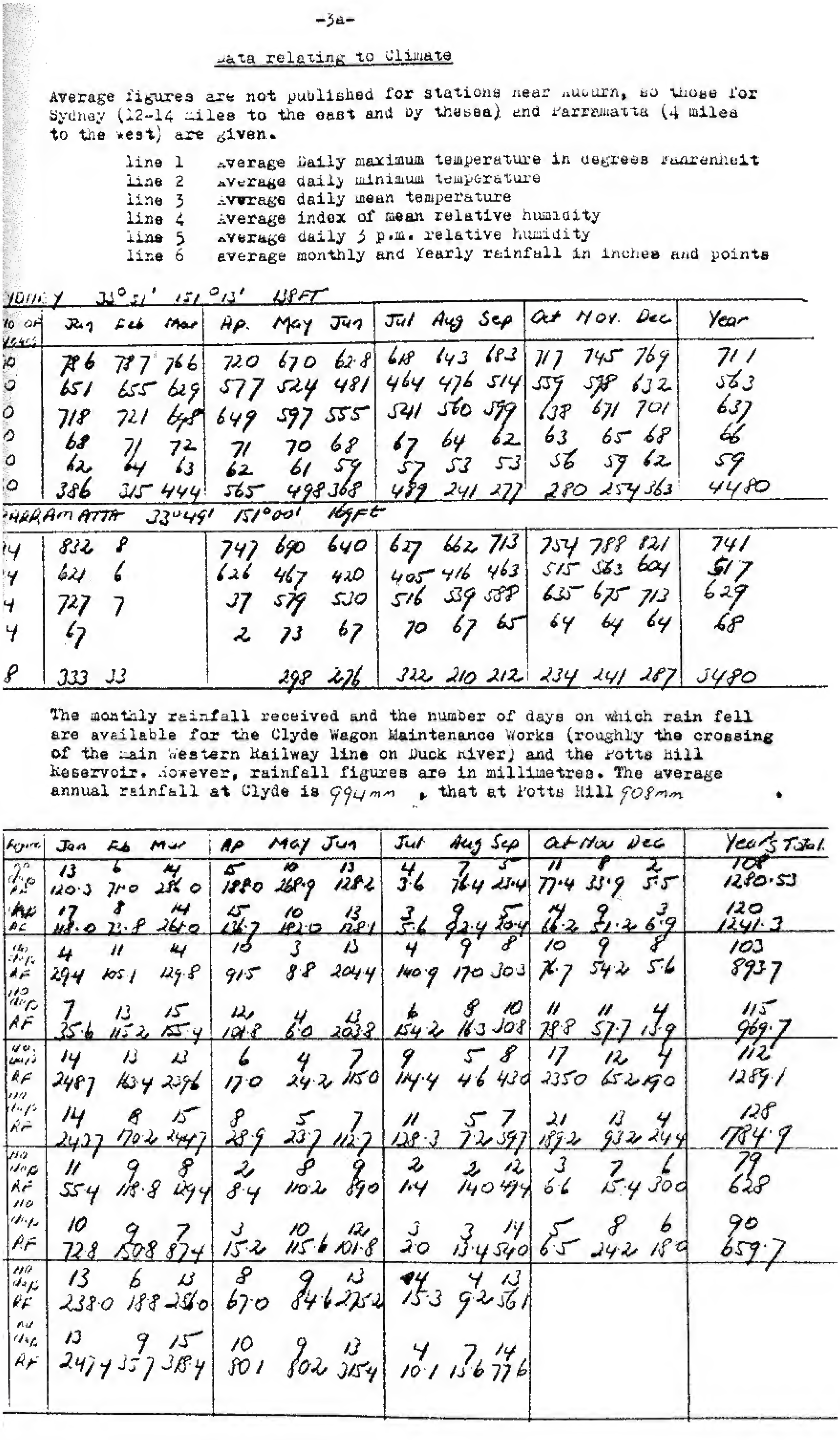
IV. The micro-environments and their vegetation

(a) The creeks, waterholes, seasonally flooded lands and drainage lines

The permanent and transient sheets of water

Only in the deeper reaches of the Duck River is water permanent and deep enough for there to be soft, quite delicate but as yet unidentified water plants which survive despite repeated, quite violent flushing during every heavy fall of rain. Soft but pliant knotweeds (*Polygonum decipiens, P. lapathifolium*) and alligator weed (*Alternanthera philoxeroides*) rooted in the banks about low water level also seem able to regenerate after floods from a straggle of stripped stems by the following growing season, the alligator weed so successfully that it takes over much of the water surface by mid summer despite the CSIRO's control programme.

The areas of semi-permanent and transient sheets of water are equally difficult environments where changes in the depth of the water, the length of time it persists and the strength of its flow, if any, can be critical for the plants that grow there. Bull-rushes (*Typha orientalis*) grow well in the dams on Carnarvon Golf Course and the semi-permanent pond in the old shallow clay pit behind the Woolworth's factory on Duck River. A succession of wet seasons has also allowed quite small colonies to spread onto a few sites that are simply moist but the river in flood is too violent for them to have colonised the normally still waters behind the Princes Road weir. Saggitaria (*Saggitarria graminea var weathemiana*) has also adapated to the changing levels of the water in the Duck River clay pits.



-3a-

Data relating to Climate

Average figures are not published for stations near Auburn, so those for Sydney (12-14 miles to the east and by thesea) and Parramatta (4 miles to the west) are given.

line 1 Average Daily maximum temperature in degrees Fahrenheit
line 2 Average daily minimum temperature
line 3 Awwrage daily mean temperature
line 4 Average index of mean relative humidity
line 5 Average daily 3 p.m. relative humidity
line 6 average monthly and Yearly rainfall in inches and points

YDNEY 33°51' 151°13' 138FT

No of years	Jan	Feb	Mar	Ap.	May	Jun	Jul	Aug	Sep	Oct	Nov.	Dec	Year
10	786	787	766	720	670	62·8	618	643	683	717	745	769	711
0	651	655	629	577	524	481	464	476	514	559	598	632	563
0	718	721	698	649	597	555	541	560	599	638	671	701	637
0	68	71	72	71	70	68	67	64	62	63	65	68	66
0	62	64	63	62	61	59	57	53	53	56	59	62	59
0	386	315	444	565	498	368	489	241	277	280	254	363	4480

ARRAMATTA 33°49' 151°00' 169FT

14	832	8		747	690	640	627	662	713	754	788	821	741
4	621	6		626	467	420	405	416	463	515	563	604	517
4	727	7		37	579	530	516	539	588	635	675	713	629
4	67			2	73	67	70	67	65	64	64	64	68
8	333	33			298	276	322	210	212	234	241	287	3480

The monthly rainfall received and the number of days on which rain fell are available for the Clyde Wagon Maintenance Works (roughly the crossing of the Main Western Railway line on Duck River) and the Potts Hill Reservoir. However, rainfall figures are in millimetres. The average annual rainfall at Clyde is 994mm , that at Potts Hill 908mm .

Figure	Jan	Feb	Mar	Ap	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year's Total
[illegible] RF	13 120·3	6 71·0	14 25·0	5 188·0	10 268·9	13 128·2	4 3·6	7 76·4	5 23·4	11 77·4	8 33·9	2 5·5	108 1280·53
[illegible] RF	17 118·0	8 72·8	14 264·0	15 136·7	10 182·0	13 128·1	3 5·6	9 92·4	5 20·4	14 66·2	9 51·2	3 6·9	120 1241·3
[illegible] RF	4 29·4	11 105·1	14 129·8	10 91·5	3 8·8	13 204·4	4 140·9	9 170	8 30·3	10 76·7	9 54·2	8 5·6	103 893·7
[illegible] RF	7 35·6	13 115·2	15 155·4	12 101·8	4 6·0	13 203·8	6 154·2	8 16·3	10 30·8	11 78·8	11 57·7	4 15·9	115 969·7
[illegible] RF	14 248·7	13 163·4	13 239·6	6 17·0	4 24·2	7 115·0	9 114·4	5 4·6	8 43·0	17 235·0	12 65·2	4 19·0	112 1289·1
[illegible] RF	14 242·7	8 170·2	15 244·7	8 28·9	5 23·7	7 112·7	11 128·3	5 7·2	7 59·7	21 189·2	13 93·2	4 24·4	128 1784·9
[illegible] RF	11 55·4	9 118·8	8 129·4	2 8·4	8 110·2	9 89·0	2 1·4	2 140	12 49·4	3 6·6	7 15·4	6 30·0	79 628
[illegible] RF	10 72·8	9 150·8	7 87·4	3 15·2	10 115·6	12 101·8	3 2·0	3 13·4	14 54·0	5 6·5	8 24·2	6 18·0	90 659·7
[illegible] RF	13 238·0	6 18·8	13 256·0	8 67·0	9 84·6	13 275·2	4 15·3	4 9·2	13 56·1				
[illegible] RF	13 247·4	9 35·7	15 318·4	10 80·1	9 80·2	13 315·4	4 10·1	7 13·6	14 77·6				

But I doubt that the water hyacinth (*Eichhornia crassipes*) and parrots feather (*Myriophyllum brasiliense*) in the small, quite shallow pond in ~~xx~~ the tip at Georges Avenue, Rookwood, are anything but recent jetsam from an acquarium that must fail. The quickly maturing rushes and sedge-like plants (*Juncus capitatus*, *J. continuous*, *J. planifolius*; *Scirpus prolifer*, *S. inundatus*, *S. chlorostachys*) that grow in and about the edge of this and other somewhat more transient sheets of water seem better adapted to the alternately flooded and sun-baked and cracked soils that occur in such areas. *Goodenia paniculata*, a fleshy rooted native perennial is competitive in somewhat similar situations if the water is less persistent. Other rushes, sedges and herbs grow well where bulldozing, digging, wheelruts and erosion cause the soil to be under water too long for most other plants to survive. Some are drought-resistant perennials, others quick-growing annuals that can mature and seed surprisingly quickly, *Cyperus tenellus* being able to go through this cycle on uneven paths and grasslands during a long spell of wet weather. The seeds of other plants such as *Senecio hispidulus* and *Erigeron floribundus* can also be washed into these short-lived pools, germinate profusely after the water recedes, and then survive with varying degrees of success.

The edges of creeks and waterholes; other drainage lines

The Duck River has a profile that has been shaped by the great fluctuations in the volume of water it has to carry. The bed is deeply incised ten to twenty feet below the plain and is either permanent pools, exposed clays and rock or shifting beds of silt and road gravel all confined between low inner banks. On one side or the other there is often a broad bench or long slope back to the outer rim of the creek and here moisture levels, humidity and perhaps nutrients tand to be at their highest particularly if the banks are wooded and shaded. But the flow of water can be sufficiently violent to flatten shrubs and even undercut and topple trees particularly where the river's course has become unstable due to the east bank of the golf course having been reclaimed. Most woody plants, therefore, now perch ~~xx~~ about the rim of the upper bank though upstream a few survivors and sekeletons suggest that trees and tall shrubs once grew down to the inner bank. Back on the plain the natural drainage pattern has been truncated but not entirely replaced by culverts and stormwater channels. The forty foot contour on map III outlines the course of four such gullies, each of them broad and U-shaped, rarely more than four to six feet deep, but still long enough to carry up to eighteen inches of water in heavy storms and to remain moist with seepage for some time after particularly where there is any shelter. Those on the west bank still flow into impermanent waterholes on their lower reaches of the sort that probably formed the swimming holes that once were found on Haslem's creek before they were replaced by stormwater channels and the waterworks of the Carnarvon Golf course.

These drainage lines seem to have been deliberately cleared of tall shrubs and trees particularly in the Cemetery where the scrub tends to occur in regimented stands well back from their edges. But the brickwork of the channels there often as not has blocked local surface drainage water which has eroded new natural lines alongside them.

Most of the plants collected can be found growing about these watercourses as well as in many other places. But others grow only on them, ~~but~~ though for a variety of reasons. On the Duck River Hakea sericea and Persoonia linearis are riverside plants probably because only there are they much protected from the fires that have killed them off on the plain. Much the same reason may explain why the only specimens of Goodenia ovata, Asterolasia correifolia, Leucopogon lanceolatus, Pomaderris lanigera, Pomaderris ferruginea, and Hovea longifolia occur on the banks of the river or the deep drainage easement on its west bank. Or it may be that some of these species are there simply because birds coming into drink have passed seeds which they have brought in from outside the sample area. Floodwaters, too, have probably introduced a number of species to the banks of the river such as the Arum Lily (Zantedeschia aethiopica), the swamp lily (Crinum pedunculatum), the hippeastrum (Hippeastrum x equestre, Dutch hybrid (?), the snow flake (Leucojum aestivum) and the maderia vine (Anredera cordifolia). Other species, particularly many of the exotics, grow on these sites because they appear to need the moister soils, higher humidity and enriched soils found there if they are to survive or to be competitive.

So aggressive are some of these exotics that they they tend to be dominants which suppress and exclude many native plants. Where soils are moistest on Duck River creepers such as jasmine (Lonicera japonica), the balloon vine (Cardiospermum grandiflorum) and occasionally Myrsiphyllum asparagoides form layer on layer of runners so quickly that few herbs and small shrubs other than the reed (Phragmites australis), fennel (Foeniculum vulgare), and watsonia (Watsonia bulbifera) escape through this canopy whilst the larger shrubs and trees are weakened by it, particularly by the fires that the creepers carry up into their crowns. Where shade is dense the wandering jew (Tradescantia albiflora) also forms dense mats. A little higher up the banks prairie grass (Ceratochloa unioloides) can be equally aggressive in season as can kikuyu (Pennisetum clandestinum) wherever it spills over the banks from playing fields. A somewhat different range of exotics tends to be dominant on cleared drainage lines that are only seasonally moist, there usually being a paspalum-couch (Paspalum dilatatum-Cynodon dactylon) association of mainly exotic grasses and herbs on such sites. The two dominants in this association show a wide range of tolerance, neither being competitive on soils that are continuously moist, both being capable of pioneering quiee dry exposed sites particularly where the soil has been disturbed, but each seeming to be at its most vigorous where the soils are quite moist for much of its growing season. However, the two more important herbs that form a substratum in this association on the Duck River (Scutellaria racemosa and Lotus angustissimus) seem to be moisture loving species that survive dry seasons either as seeds or as a fleshy root system. In Rookwood cemetery this association (but without skullcap, apparently) is often replaced by stands of Watsonia bulbifera so dense that they exclude most other plants. But this species also fails where soils are under water for any length of time and gradually thins out upslope to occasional scattered plants.

Apart from the common reed (Phragmites australis), which is found only within the banks of the Duck River, most of the native species that prefer moist soils seem tolerant of a range of habitats. Even quite soft, moisture loving herbs such as the pale knotweed (Polygonum decipiens) and the common ranunculus (Ranunculus lappaceus) can grow in places that are simply damp and sheltered whilst waterbuttons (Cotula coronopifolia) can grow if the soils are simply seasonally damp. Shrubs and trees such as Casuarina glauca, Callistemon salignus, Melaleuca linariifolia and Leptospermum flavescens seem tolerant of sites near permanent or seasonalwater, damp sites, or even slopes in the caseof the swamp oak. Tree species that obviously grow and reproduce best where there is permanent water (Angophora floribunda on Duck River) or about impermanent waterholes (the fine stand of Eucalyptus amplifolia about the gully at Wellington road) seem even more adapatable and able to extend out onto the undulating plain (New Street and St. Johns Road for the red gum, Kibo Reserve and Kingsland Road for the Angophora). Given the range of habitats towhich all these species can adapt probably none formed dominant stands on the permament and seasonalwatercourses but were simply more common in the original woodlands at these places. The stands of swamp oak in the Cemetery and those of Angophora floribunda and the red gum on Duck River seem recent and are probably due to disturbance.

(b) Exposed soils and subsoils.

Cool grass and scrub fires are constantly exposing thetopsoil but in most seasons it is quickly protected from damage by regeneration from roots, stems and seeds. Where it is not or/where the subsoil is brought to the surface by erosion or interference the habitat becomes a far more difficult one for plants. Soils that become compacted, baked hard by the sun, and polished by the wind and the rain offer few rootholds other than the fractures that occur in these vertically structured soils. Subsoils are even more difficult for plants to colonise, particularly the subsoils on the Duck River sandstones. That rock breaks down into a finely divided clay that is sufficiently unstable on slopes for the surface run-off and perhaps even the impactof raindrops to undermine seedlings or to overwhelm them with debris. The red clays are also easily eroded. On such sites each pioneering plant must result from a delicate balance that allows for the chance lodgement of a seed on bare and often sloping ground, its nurture by rains sufficient to keep it moist yet notthat heavy thatthey undermine or swamp the seedling, and shelter that neither suppresses it nor allows a few days of bright sunshine to dessicate the seedbed.

Yet plants can adapt to these exacting requirements and the tougher and more prolific among them can build up into quite large populations. If there is a source of seed even seedlings of tree species such as *Eucalyptus eugenioides*, *E. amplifolia* and *Angophora floribunda* take on the bared subsoil of the breakaways in the clay pits and gullies on Duck River, 1978 having been a particularly good year for the germination of Angohoras. However, shrub species are more usual with those species with seed that has adaptations that ensure it isspread wide perhaps being the first to co lonise such areas. *Cassinia arcuata*, which has wind blown seed, is often the most commonand tallest shrub and it may be that once established it attracts birds which bring in seed of the tougher wattles (*Acacia falcata*, *A. longifolia*, *A. brownii*, *A. pubescens*) and pea-flowered plants (*Pultenaea villosa* being the most common though *Daviesia ulicifolia* and *Dillwynia juniperina* may be present). Scattered tuftsand tussocks of tough native and exotic grasses are also well-represented (*Danthonia purpurascens*, *Entolasia stricta*, XXXXXXXXXXXX *Eragrostis brownii*, *Dichelachne sciurea*; *Paspalum dilatatum*, *Cynodon dactylon*), possbily because their seed is windblown or spread by animals, and there may be other ground cover such as XXXXXXXXXX *Astroloma humifusum* and *Hardenbergia violacea*. But *Kunzea ambigua*, though often ultimately dominant on such soils, maybe absent if there are no fruiting specimens nearby as the seed seems spread mainly by windrthrow orwater. *Hakea sericea* is an equally prolific species, if present, though how so large-seeded a species the seedlings of which are rarely found more than a few yards from their parents came to be so widespread in the district is a nice question. Indeed, many of the native species that grow in these exposed sites are so light-demanding and their seedlings so intolerant of overmoist and shady conditions that they may once have been chancesurvivors in the original woodland. But nowadays it is the very clearing and burning that once may have cause d an explosive increase in their numbers and spread them wide that threaten their very existence.

No doubt in the fullness of time the soils on these disturbed areas once reverted to an eucalypt woodland. Today that succession need not occur but may be checked by fire, further clearing, or be the interposition of a new and perhaps more stable phase, that of grasslands which include a high proportion of exotic species. On parts of the clay pits on the east bank of Duck River a form of the paspalum couch and herb association and a mixed pasture of those and native grasses such as

Dichelachne sciurea and Eragrostis brownii may well establish if the area is ever kept free of mini bikes. However, wherever Cassinia arcuata grows well in these pits and on parts of nearby sewerage and drainage easements it and its associates, Pultenaea villosa and the wattles, seem to be able to keep the grasses sufficiently in check for further shrub seedlings to take. It may be that these areas, once the soil profile becomes more mature, could in turn be invaded by Melaleucas or even eucalypts and ultimately become woodlands. But wherever the genes of Kunzea ambigua are present the sites with disturbed soil profiles would seem first to become Kunzea scrub, which is the typical vegetation type on much of the southern slope of the Crematorium Hill and the rim of a small clay pit on Duck River at Princes Road.

Kunzea ambigua with its prolific regeneration, its need for intense light, its spreading habit of growth and dense canopy, its height, and the large amount of litter it sheds, quickly becomes dominant in these scrubs. Other taller shrubs such as the wattles, occasional melaleucas, particularly Melaleuca nodosa, Hakea sericea and Casuarina littoralis seem able to remain part of the community by their natural increase in height but are able to reproduce only where the ground is more open. Small shrubs such as Cassinia arcuata, Pultenaea villosa, Daviesia ulicifolia and the ground cover of Astroloma humifusum, Hardenbergia violacea, Danthonia purparescens, Entolasia stricta and so on at best linger on before gradually being suppressed unlessthey are able to colonise the edges of the scrub. Tree species are rare in theexisting scrubs, but are so everywhere in the Cemetery and on the allotment on Duck River where the fragments of it occur. Seedlings of Angophora floribunda do occur cheek by jowl with the Kunzea at Princes road and eucalypt seedlings can establish on the soils of breakways but I have not seen them do so in direct competition with the scrub. However, the Kunzea, wattles and the like are relatively short-lived and the scrub would gradually be opened up by deaths, windthrow and fires to the invasion of other species, particularl y once the soil profile became more mature. Seedling eucalypts might only establish by chance, of course, but most seem to do that anyway. Ultimately they would tend to dominate and suppress the scrub and it would revert to eucalypt woodland in much the same way as some of the ti-tree scrubs are now doing.

(c) The Plain and Undulating Land

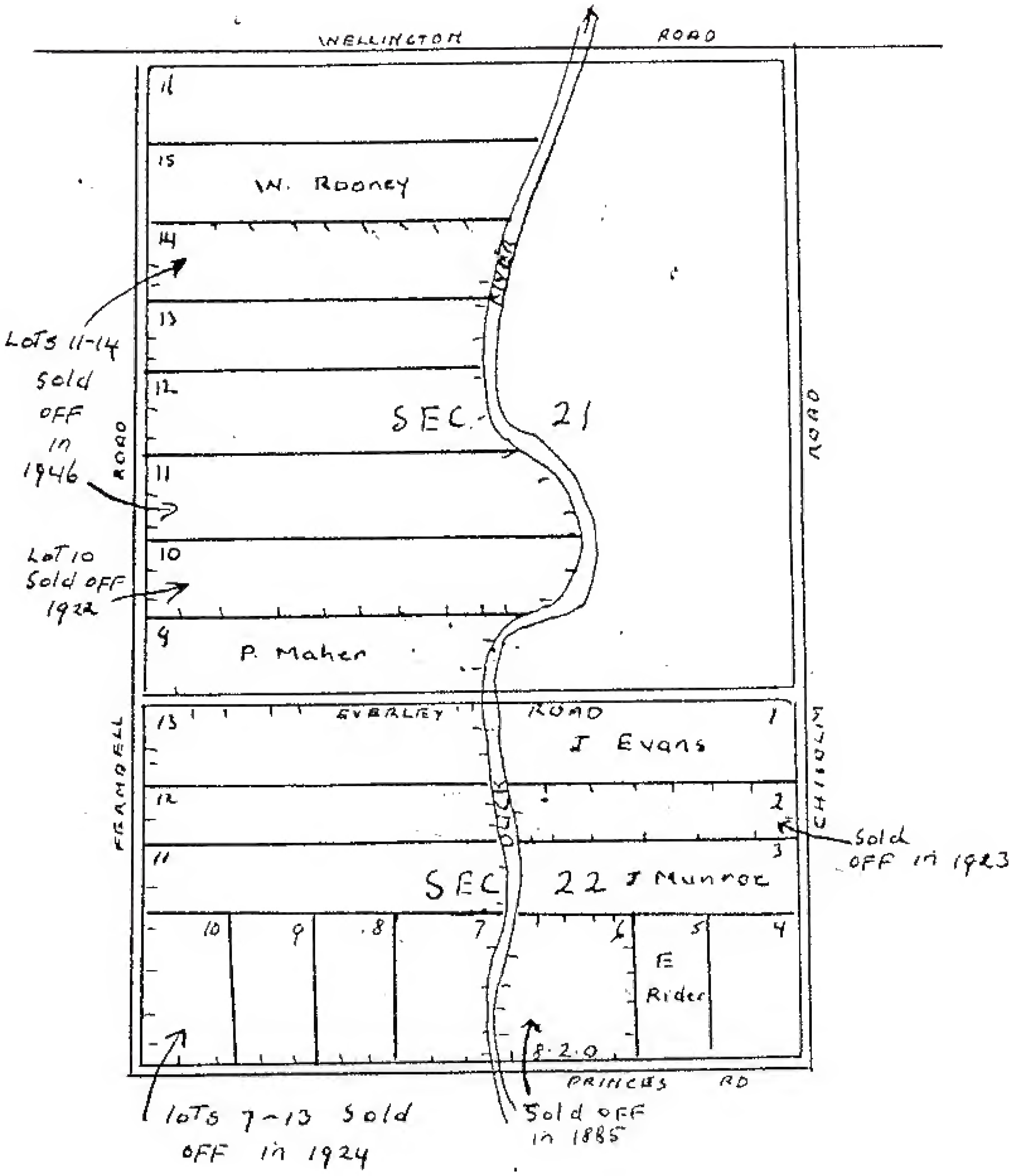
Here the micro-environment seems dependent on and differs in each vegetation type. And the structure and composition of the vegetation, within the range of possibilities nature allows, is determined nowadays very much by man and fire.

At Rookwood 'the bush' and the 'burial grounds' have always been incompatible and 'the bush' also irreconcilable with the Victorians' concept of 'a necropolis' as a beautiful garden of lawns, shrubberies,

LARGE HOLDINGS

CHISOLM ESTATE

DUCK RIVER



▭ Holding bought by J.A. Curtis off Chisolms 1882-3 avenues of trees, ponds and fountains. Yet the bushland survived as manageable Themeda grasslands and depauperate scrubs along swampy drainage lines and gullies and out of sight over the watershed towards Chullora. It did so and now even encroaches onto the older burial grounds only because of a latterday preference for cremation that has left some waste land and impoverished the various denominational trusts. But fire, until recently, became the trusts' one economic tool of management and grasslands, scrubs, shrubberies and avenues have been indiscriminately burned for many years. Grasslands and scrubs survived, established an uneasy equilibrium with one another, and seemed likely to become permanent vegetation types until grave-digging became mechanised and bulldozers were able to make short shrift of both. The old State Hospital grounds (which once included the Carnarvon Golf Course) have been even more completely cleared of all but a few veteran trees and shrubs, perhaps because 'The Old Men's Home' was expected to be self-sufficient in vegetables, milk and cheese. However, it may well be that these areas and the cemetery~~x~~ were at least partly cleared for grazing much earlier as they were all ~~px~~ part of the 1340 acres of the 2640 granted Richard Hyde Potts which were ~~repearced~~ repurchased by the crown ~~by~~ (about 1860?).

On Duck River the relation between the present vegetation types and the past use of the land is much clearer. On Map III grasslands give way abruptly to gum and ti-tree scrub at the old property boundaries, the one stand of tall woodland that has re-established over some seventy years is on an unusable part of the Hillston market garden, and the one other area of low woodland is on an isolated part of a property on the west bank. Once the whole of the survey area was part of a 600 acre grant given in 1823 to James Chisolm, variously seargent in the NSW corps, proprietor of the Thistle inn in George street, businessman and then grazier. The grant ultimately became part of a larger estate, 'Everley', named after Chisolm's property at Redfern, but whether or not it was much cleared and worked in with the Chisolm family's other properties at Narellan, Goulburn and the Bland I can't say. But increasingly it became more profitable to subdivide and sell the land though, being low lying and near the river, it was surveyed into farmlets (see Diagram I) and not into suburban allotments~~x~~ of the sort that seemed likely for a time to turn the ridge towards Auburn into another middle class Arcadia like Strathfield. In 1882-3 all but eight of the twenty-one allotments into which the survey area was subdivided were sold to J.A. Curtis who, perhaps significantly, was a Sydney timber merchant and he, in turn, sold all but 8½ acres to Robert Chadwick in 1885. The various members of the Chadwick family (some of whome are sometimes described in the transfer documents as 'surveyors') held this property intact until 1922-4 when the southern allotments were sold but it was not until 1946 that they parted with the area which now includes the best preserved areas of bushland. That bush, I would guess, survived so long simply because it was on this large and possibly speculative holding. The market gardeners, dairymen and the like usually could ill-afford to let their land lie idle.

If the exact chronology of all this destruction is in doubt its outcome is not. No stand of the original vegetation survived not even on the Hillston property where the fine group of eucalypts has regenerated since 1902 from a cleared but badly placed chicken farm. Most of the original species no doubt still occur as clearing with axe and fire without years of laborious grubbing and weeding is somewhat akin to sowing dragons' teeth. The native species able to regenerate from rootstocks, lignotubers and stumps range through the full gambit of growth forms from ferns, soft herbs, creepers and shrubs to all the dominant trees. Many of these and other species also seed profusely and would have found a cleared and burned seebed ideal for their regeneration. Proof of the native species' tough, enduring qualities lie both in the proportion they still form of the species list and the way in which they still exclude all but a few exotics from most stands of regenerated scrub. What was destroyed, and that probably quite quickly and perhaps iredeemably, was the structure and composition of the original vegetation. For what was once probably an area of tall woodland or dry schlerophyll forest dominated by ~~an~~ *Eucalyptus moluccana-E. fibrosa* association has been reduced to mainly the grasslands and depauperate eucalypt and melaleuca scrubs shown on the maps. Both are unstable, the grasslands being prone to invasion by shrubs and trees, the scrub having a propensity to revert into woodland. But fires are frequent, as often as once in two years if sufficient dead litter accumulates about the base of grass tussocks to fuel ~~start~~ the cool grass that are most common. Most woody plants lack the chance to re-establish and raise their crowns above the flames before they are burned back once more. Those that are tall enough to be unaffected rarely have the girth to be free of the risk of being axed back to fire sensitive regeneration from stumps. Systematic clearing may have first formed the grasslands and scrubs but nowadays vandalism seems sufficient to keep them indefinitely as the dominant vegetation types in most places.

(1) The Grasslands

1. Grasslands in which almost pure stands of *Themeda australis* are dominant occur where the land has been cleared a long time and little interfered with other than by firing. In the Cemetery the largest areas are in the unused parts of the Independentand Methodist burial grounds but the species has also re-established its dominance on the western slopes of the Presybyterian burial ground no. 2 despite the massive disturbance there when it was in use between 1890 and 1910. On Duck River the one large stand of *Themeda australis* is back a little from Wellington Road and is more an open, low parkland with a scattered upperstorey of eucalypts and ti-tree. Elsewhere on the River most colonies of the grass are small and in open glades in the scrubs and woodlands. The two variants

of the species at Rookwood form discrete though adjoining populations, the one a much more robust, broader-leaved and more glaucous form, the other a finer, greener and smaller one which is the only form found on Duck River. Both are vigorous perennials that flower and seed prolifically in early summer unless burned in spring, a dry season seeming only to affect the height of the culms. Tussocks are closely spaced, leaves arch over between them to almost touch, root systems are fibrous and aggressive so that there is little light or surface moisture in an undistrubed stand for the seedlings of competing species or, indeed, for those of *Themeda*. Yet other species are often associated with the stands, many of them ground orchids (*Diuris*, *Microtis* & *Thelymitra* spp., mainly at Rookwood), herbs with bulbs or corms (*Hypoxis hygrometrica* and naturalised South African plants such as *Romulea longifolia*, *Freesia refracta*, and *Ixia*, *Watsonia* and *Tritonia* spp., the latter three only at Rookwood), *Patersonia longifolia* (Rookwood), *Xanthorrhoea* and *Lomandra* spp.; and a few low shrubs that can survive if fires are not too frequent to stop them regenerating from rootstocks (*Lissanthe strigosa*, *Chorizema parviflorum*, *Bossaea buxifolia*, *Platysace ericoides*, last species Rookwood only).

These grasslands persist only because they are often burned. Yet fire, when followed by wet weather probably helps to establish the seedlings of shrubs and trees which, were they able tosurvive and to build up into large popplations, would ultimately supress the light-demanding *Themeda australis*. But in the cemetery, so far, the balance seems to favour the grasses. Seedlings of some of the old avenue plantings such as *Pinus radiata*, and *Eucalyptus saligna* do establish but seem to have been no more able than the more common of the native eucalypts (*Eucalyptus resinifera* and *E. tereticornis*) in growing into fruiting and flowering specimens as distinct from transient populations of saplings. *Angophora bakeri* with its rough, more fire-resistant bark and its early flowering and fruitng habit might be more successful were it more widepread but, for whatever reason, it is not. *Leptospermum attenuatum* therefore is the one shrub species that has built up large populations of mature specimens but these are mainly in the burial grounds and in any case seem naturally to be scattered and to form crowns sufficiently open to be tolerant of the grass. *Melaleuca nodosa* probably poses the grestest poxtential threat to these grasslands being a species that is able to re-generate on a wide range of sites, one that is fast growing, quickto flower and well able to build up a population of lignotubers that reganerate after fire and provide an environment suited to the establishment of other shrub species inwhich far more shade-tolerant grasses than *Themeda* are soonsupressed. But fires in the cemetery keepthe stands to heights barely more than one or two metres high and probably help confine them to the moister soakage lines. Some of the more common associates of *Melaleuca nodosa* in these small scrubs are themselves less of a threat to the grasslands as they are more fire-sensitive, this though the pinnate acacias (*Acacia parramattensis*, *A. dealbata*, *A. pubescens*) sucker from the old root system after fire and the heath-like pea flowered species such

Pultenaea villosa and *P . microphylla* re-generate profusely from seed. Yet they survive in the scrubs and in more sheltered places about the edges of the grasslands and within the kerbing of graveswhere the odds against their being burned are higher and could increase quite rapidly in numbers if fires were less frequent.

In the open parklands on Duck River the situation is more complex as the eucalypts (*Eucalyptus molucanna*, *E. fibrosa ssp. fibrosa*, *E. eugenioides* *E. longifolia*, *E. resinifera*) and the ti-tree (*Melaleuca decora*) must once have been able to regenerate successfully for them to form an upper storey to the stand of *Themeda australis*. However, few gum or ti-tree seedlings appear to have established for quite some time and the stand comes close to having an even-aged appearance and may be the first phases of regeneration after these allotments were cleared when grasses may or may not have been as common as they are now. Most eucalypts are roughly fifteen to twenty-five feet high unless they have been axed or cut backby fire. The ti-treeis also old most of the plants being from perhaps eight to fifteen feet high though the population of smaller stems with diameters from 3-5cm is of indeterminate age as such fire-sensitive specimens can regenerate many times when damaged. The lack of young eucalypts is partly due to the absence of many mature, fruiting specimens but even where these are found there are no seedlings and few young plants. The ti-tree, though also slow to mature, does now flower freely and set seed and it may be there are no seedlings because the quite exacting conditionsthey need if they are to establish are not being met. Young plants of *Melaleuca decora* are rare everywhere in the district but the one congested, even-aged stand of several hundred specimens I have come across is on a site at Rookwood so seasonally moist that I wouldguess regeneration might be abundant in a period of quite wet weather on a suitable seed bed. But the most favourable seedbeds in these parklands are within the occasional small scrubs which already have a fairly full complement of shrubs. Here the canopy is closed and casts sufficient shade to exclude all grasses other than scattered tufts of shadetolerant species such as *Entolasia marginata*, *E. stricta* and *Microlaena stipoides* and there is much bare ground. Once the canopy is opened up by fire, the accumulated store of seed is better able to germinate on ground that has a mulch of scorched and partly burned ti-tree and gum leaves and the seedlings are the better able to survive as there is broken shade and no established root system near the surface. The nearby grasslands, when burned, are often deficient in seed,the ground tends to bare and unshaded at first, and such plants that do establish can be quickly overwhelmed by the leaves of the regenerating tussocks and deprived of moisture by their established, quite aggressive root systems. Clearly there is no one, simple explanation why the balance has been tilted in favour of the grasses in these parklands. But here, as at Rookwood, they form a micro-environment favourable to fire and, being in public places near residential areas

areas, are probably being burned so often that the tree and shrub species that otherwise would supplant thegrasses are now unable to re-establish their dominance.

ii. No onespecies of grass is dominant on cleared lands where the original grasses have been much disturbed by grazing, clearing, levelling and so on. Usually the mix is of native species (*Dichelachne sciurea*, *Eragrostis brownii*, *E. phillipica*, *Agrostis aemula*, *A. avenacea*, *Aristida vagans*, and *Danthonia spp*, particularly *Danthonia purparescens*) with a larger proportion of exotics, particularly of the species that are dominant on the cleared, seasonally wet drainage lines (*Paspalum dilatatum*, *Cynodon dactylon*, *Briza minor*, *Setaria geniculata*). *Themeda australis*, if it occurs, tends to form small isolated colonies or solitary tussocks as it is killed off by over-grazing and does not easily re-establish on disturbed soils. The density of the sward varies with the season and the moisture status of the site and may be very close on drainage lines even in dry seasons but quitesparse and open in exposed places. Usually there are herbs, some of them such as *Centaurium tenuiflorum*, *C.erythraea*, *Linum trigynum* and *Wiseoates orontium* tolerant of a wide range of sites, others such as *Lotus angustissimus*, *Scutellaria racemosa* andso on forming a substorey to the grasses on moistersoils. A variety of emergents such as the dock (*Rumex crispus*), *Verbena bonariensis*,, thistles (*Sonchus spp. Cirsium vulgare*) and rushes (*Juncus spp.*) also occur. Grasses such as *Vulpia bromoides*, *V. myuros* and *Sporolobus africanus* near tracks and kikuyu (*Pennisetum clandestinum*) near dumped spoil can build up quite sizeable local populations or even, in the case of kikuyu, exclude most competitors.

There seems to be an uneasy balance between the species in these stands. Differences in their growth habit and their seasonal flush of flowering no doubt help the low annual, *Briza minor*, and the slender native perennial, *Dichelachne sciurea*, build up such large populations in a pasture which in winter often seems to be almost entirely coarse, leafy tussocks of paspalum. But their quick response to the first warm spring rains would probably be of little avail in the long run were the more aggressive but more warmth demanding paspalum not checked from becoming rank and choking out most of it competitors by repeated burning. The composition of the grassland also changes with the moisture status of the siteand might therefore also vary over a cycle of wet or dry years. The moistest sites are very much the preserve of the exotic grasses and herbs with only *Agrostis spp*. among the native grasses being at all common thoughboth *Dichelachne sciurea* and *Microlaena stipoides* may be present. But native species such as *Dichelachne sciurea*, *Eragrostis brownii* and *Aristida vagans* are much more successful on dry sites and are ableto bloom and set seed prolifically in a dry season such as that of 1978/9 when the paspalumand couch remain stunted and scarcely able to renew their crowns let alone form culms. In such areas, indeed, these grasslands may be susceptible to invasion by *Themeda australis*. For that grass seems to be re-establishing on the dry exposed soils along the southern boundary and along the tracks through the old dairy on Wellington Road at Duck River. And if such an invasion is possible during the recent cycle of wet years it is conceivable that in the past the grass could also re-establish its dominance on the well-drained slopes of the older burial grounds in the Cemetery.

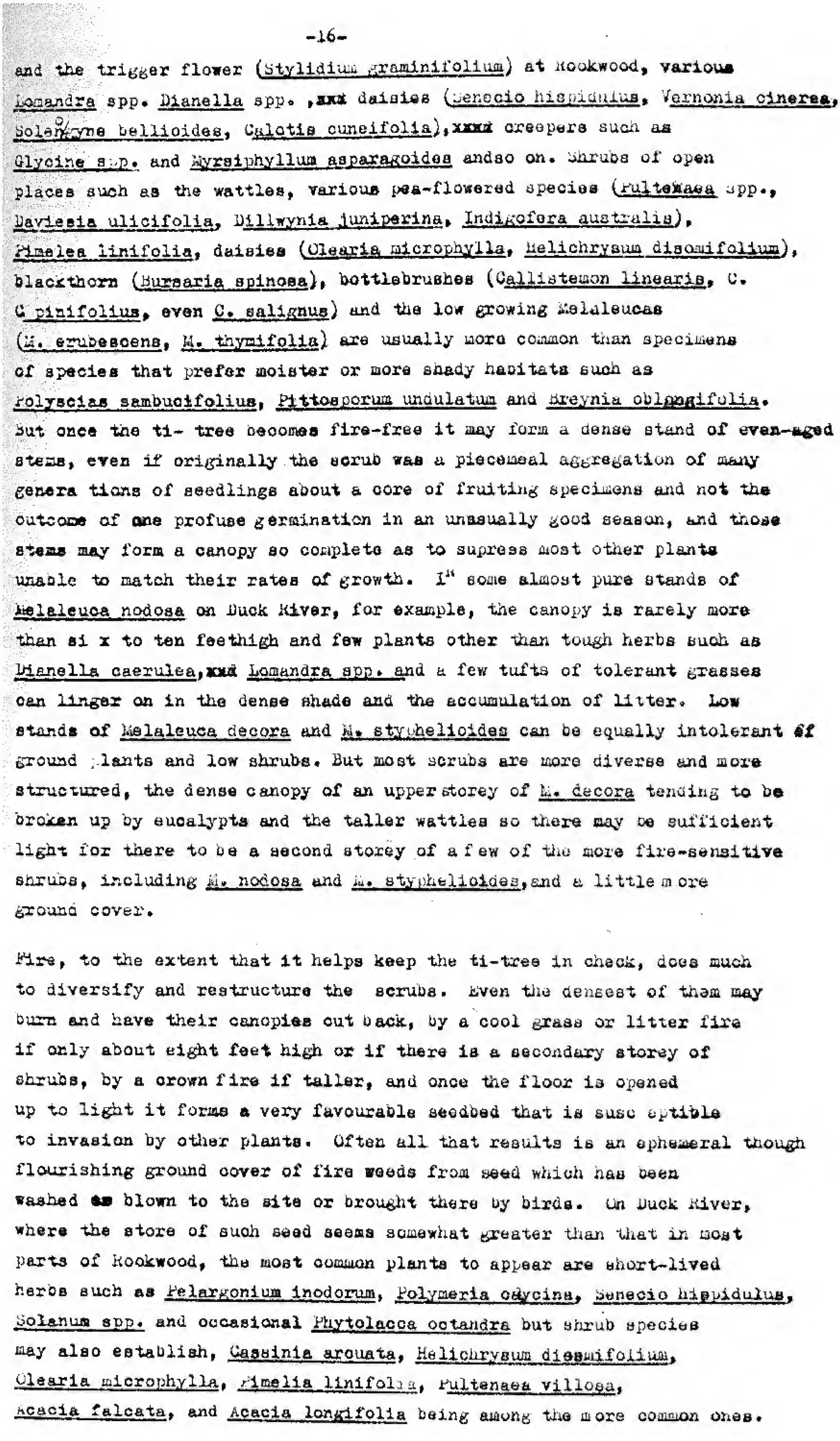
Most of these areas seem to have been disturbed too recently for there to be much evidence of their having been invaded by shrubs or trees. However, about Everley Road on the east bank of Duck River a population of wattles (*Acacia falcata*, *A. longifolia*, *A parramattensis*) and pea-flowered species (*Pultenaea villosa*, *Teline monspessulana*) have built up among the grasses on dumped heaps of spoil. The same species and others from the rim of bushland along the river (*Eucalyptus moluccana*, *E. eugenioides* or *E. globoidea*, *Angophora floribunda*, *Lomandra longifolia*, and even *Clematis aristata*) are invading the grasses that have taken over the western end of the old Hillston market garden. However, both areas have been free from fire for at least three years, probably more. And though they suggest that grassland is only a transient vegetation type in this district the succession to woodland must surely be a very slow one as even the Hillston property, isolated though it is by the creek and road, has nonetheless suffered a quite violent fire in recent years that has killed or seriously weakened a number of large eucalypts, cut back the regenerating trees, and led to the formation of a fairly mature second generation of wattles and pea-flowered species.

(2) Scrubs and low woodlands

Ti-tree and eucalypt scrub (or variants on it in which such species as *Angophora bakeri* and *Syncarpia glomulifera* are also dominants) is the most common type of vegetation on land that has been partly cleared or which has been recolonised by shrubs and trees. In places on the west bank of Duck River the eucalypts have become dominant and are tall enough to form a low woodland.

At their simplest the scrubs are dense stands dominated by one or another of the three more important ti-trees, *Melaleuca decora*, *M. nodosa* and *M. styphelioides*. Scrubs in which the dominant storey is almost solely of *Melaleuca nodosa* are not as common as might be expected of this aggressive and tolerant species, the only one that is visibly and actively colonising new ground at present, but they do occur in Rookwood and as small stands on the Duck River. However, they are rarely taller than perhaps nine to fifteen feet and, as the stems and crowns are quite fire-sensitive, are at constant risk of being cut back by the flames, often to ground level. *Melaleuca styphelioides* is also fire sensitive and an indifferent coloniser (and therefore, perhaps, has been eliminated from Rookwood) which is rarely a dominant shrub. But when freed from fire, as it has been by the exposed sub-soils of the deep drainage easement on the west bank of Duck River, it can form tall scrubs which so far are up to about fifteen to twenty feet high. *Melaleuca decora*, like *M. nodosa* is almost ubiquitous and often is dominant in taller scrubs up to fifteen to twenty feet high. Height for height it seems to be able to build up a stem with a greater diameter and perhaps a greater thickness of fire-resistant bark than either *M. nodosa* or *M. styphelioides*, its crown seems to have a distinctly better ability to re-establish if scorched and, despite its thick-stemmed, umbrageous habit in the open, can form slender stems and narrow crowns in dense stands that enable it to grow up into the canopy even of woodlands in competition with other species, particularly the eucalypts. More usually the scrubs are not monospecific stands of a dominant ti-tree but mixes of several of the species mentioned and the saplings of some of the rough-barked and fibrous barked trees that are most conveniently described as being 'ti-tree and eucalypt scrubs'. The trees (*Eucalyptus fibrosa ssp. fibrosa*, *E. resinifera*, *Angophora bakeri*, *Syncarpia glomulifera*, the latter two in Rookwood only; *E. longifolia* and *E. moluccana*) normally do not form fairly pure stands, the one exception being that in the Presbyterian cemetery dominated by *Angophora bakeri*, a species which has reproduced so freely from seed and suckered so aggressively from the base after fires as to have formed a low scrub four to eight feet high. Elsewhere, the tree species have growth forms and a frequency that range from low, fire-sensitive growth from occasional lignotubers that may be part of the groundstorey in a scrub, through specimens that are co-dominants with *Melaleuca decora* in taller scrubs, to stands on the west bank of Duck River up to thirty five to forty feet high that are becoming dominants in their own right and forming either grassy low woodlands, usually where *Melaleuca decora* is an important element in the stand, or low shrubby woodlands where it is not.

The scrubs owe their form and their very existence to the ti-trees. The innate vigour, adaptability and persistence of the three main species have enabled them to profit most from the clearing of the original woodlands so that nowadays they are almost ubiquitous, dominant in most stages of the succession, and the species to whose ecology others, even the eucalypts, have to adapt if they are to survive. However, when young the ti-trees are rarely so dense that they are able to exclude or suppress other plants and usually there is a wide range of low shrubs, herbs and grasses present. Wiry panic (*Entolasia stricta*) is the grass most able to adapt to them but the shade tolerant meadow rice grass (*Microlaena stipoides*) is almost as common and usually there may be specimens of most of the native grasses collected present. Scattered herbs of open grassy places and the woodlands may also occur - such plants as the ground orchids (*Microtis* spp., *Diuris* spp., *Thelymitra* spp.)



and the trigger flower (Stylidium graminifolium) at Rookwood, various Lomandra spp. Dianella spp. ,xxx daisies (Senecio hispidulus, Vernonia cinerea, Solenogyne bellioides, Calotis cuneifolia),xxxx creepers such as Glycine spp. and Myrsiphyllum asparagoides andso on. Shrubs of open places such as the wattles, various pea-flowered species (Pultenaea spp., Daviesia ulicifolia, Dillwynia juniperina, Indigofera australis), Pimelea linifolia, daisies (Olearia microphylla, Helichrysum diosmifolium), blackthorn (Bursaria spinosa), bottlebrushes (Callistemon linearis, C. C pinifolius, even C. salignus) and the low growing Melaleucas (M. erubescens, M. thymifolia) are usually more common than specimens of species that prefer moister or more shady habitats such as Polyscias sambucifolius, Pittosporum undulatum and Breynia oblongifolia. But once the ti- tree becomes fire-free it may form a dense stand of even-aged stems, even if originally the scrub was a piecemeal aggregation of many generations of seedlings about a core of fruiting specimens and not the outcome of one profuse germination in an unasually good season, and those stems may form a canopy so complete as to supress most other plants unable to match their rates of growth. In some almost pure stands of Melaleuca nodosa on Duck River, for example, the canopy is rarely more than six to ten feethigh and few plants other than tough herbs such as Dianella caerulea,xxx Lomandra spp. and a few tufts of tolerant grasses can linger on in the dense shade and the accumulation of litter. Low stands of Melaleuca decora and M. styphelioides can be equally intolerant of ground plants and low shrubs. But most scrubs are more diverse and more structured, the dense canopy of an upper storey of M. decora tending to be broken up by eucalypts and the taller wattles so there may be sufficient light for there to be a second storey of a few of the more fire-sensitive shrubs, including M. nodosa and M. styphelioides,and a little more ground cover.

Fire, to the extent that it helps keep the ti-tree in check, does much to diversify and restructure the scrubs. Even the densest of them may burn and have their canopies cut back, by a cool grass or litter fire if only about eight feet high or if there is a secondary storey of shrubs, by a crown fire if taller, and once the floor is opened up to light it forms a very favourable seedbed that is susceptible to invasion by other plants. Often all that results is an ephemeral though flourishing ground cover of fire weeds from seed which has been washed or blown to the site or brought there by birds. On Duck River, where the store of such seed seems somewhat greater than that in most parts of Rookwood, the most common plants to appear are short-lived herbs such as Pelargonium inodorum, Polymeria calycina, Senecio hispidulus, Solanum spp. and occasional Phytolacca octandra but shrub species may also establish, Cassinia arcuata, Helichrysum diosmifolium, Olearia microphylla, Pimelia linifolia, Pultenaea villosa, Acacia falcata, and Acacia longifolia being among the more common ones.

Occasionally these seedlings may come up so profusely about the edges of a scrub as to choke the site and are gradually thinned out by lack of moisture and light as they compete with one another and with the regenerating basal suckers and crown shoots of the ti-tree. The plants, therefore, may be short-lived, but depending on when they establish and the seasons that follow some (usually the Cassinia, Pimilea, and some of the Helichrysum and Olearia) may bloom in their first year, others in their second or in following years, the wattles being the last to mature and often the only ones that are able to grow up into and diversify the canopy. More rarely, at least nowadays, eucalypt seedlings can invade the scrub of ti-tree in much the same way, there being occasional tall stands of *Melaleuca decora* in Rookwood where young, quite slender stemmed, small crowned and very fire sensitive specimens of *Eucalyptus resinifera* are fighting for a place in the canopy.

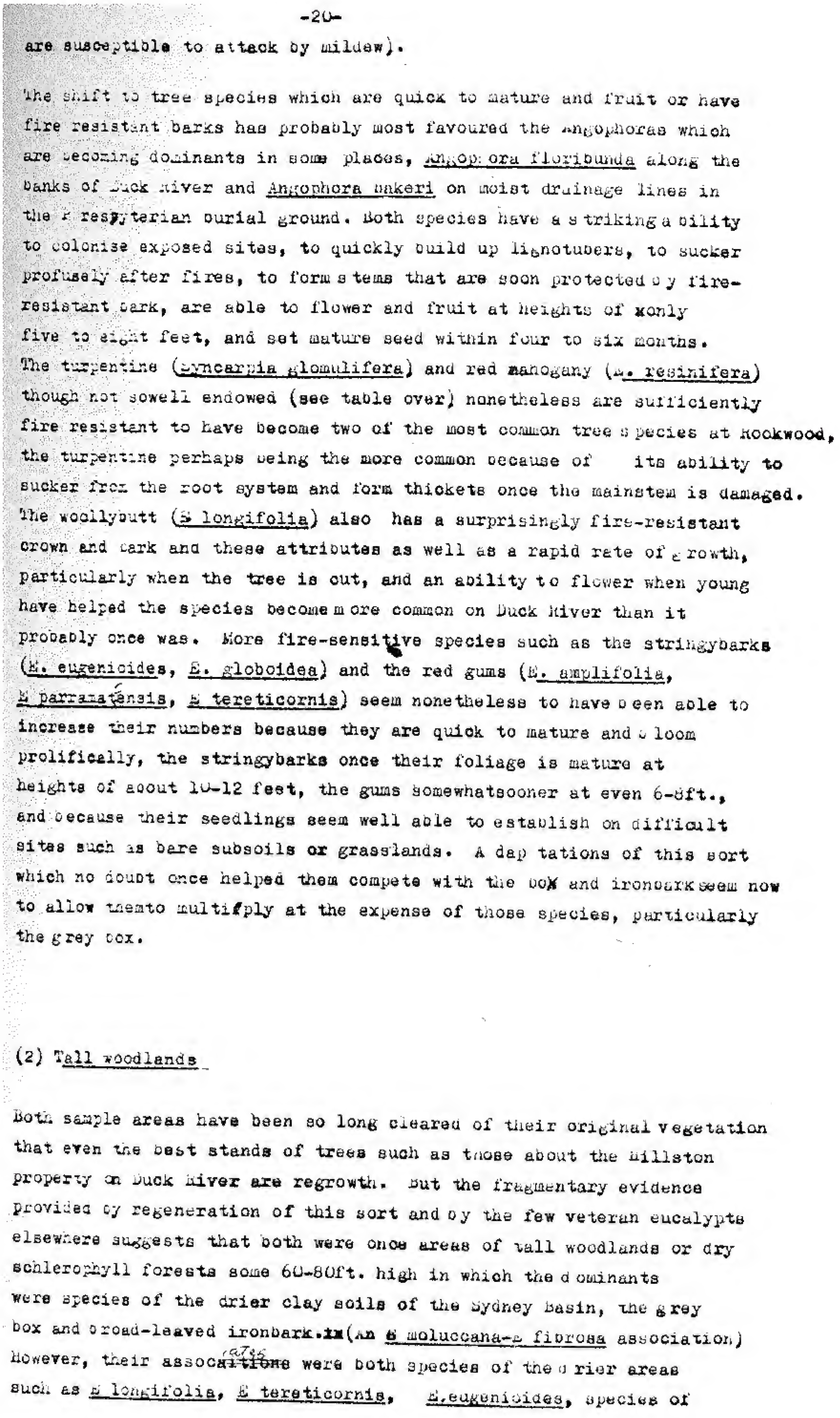
But fire can also simplify the scrubs if it is too violent or too frequent. On the west bank of the Duck River in the summer of 1975 (I would guess) a scrub fire killed off many of the emerging eucalypt dominants with stems of less than 10 cm. D.B.H. and reduced many others to lignotuberous regeneration that is now simply the equal of the original understorey of ti-tree. Populations of some of the fire-sensitive wattles and pea-flowered species also seem to be rebuilt only slowly after fires which in any case need to be at least less frequent than once every two years if the gene pool of even the most prolific and quick-maturing species is not to be put at risk and exhausted. Neverthless, the interplay between fire and the natural growth habits of the ti-tree can also help create new opportunities for other species to recolonise even the densest, mono-specific scrub. By constantly pruning off the lowest branches, by weeding out weaker specimens, and by stimulating the more vigorous ti-trees to grow up wards the ground is gradually opened up to light and in this dappled shade a dense groundstorey can gradually develop, one that is probably the richer in species and growth forms of eucalypts are common in these tall shrubs and low woodlands as their canopy is more open than that of the ti-trees.

Grasses are the most common ground cover wherever *Melaleuca decora* is an important constituent of the tall scrubs and low woodlands, perhaps because of fire and because of the shade cast by the canopy, or perhaps because of some past factor in the succession that eludes me. At its simplest, the sward is made up of species distributed in ways that correlate nicely with the moistness and the light status of the different sites. At the most exposed, seasonally driest end of the spectrum in grassy glades kangaroo grass (*Themeda australis*) may be dominant; in moister areas of dappled shade meadow rice grass (*Microlaena stipoides*) is most common; between the two extremes there tends to be a mixed stand with meadow rice grass, margined panic (*Entolasia marginata*) and hedgehog grasses (*Ehhinopogon ovatus*and *E. caespitosus*) more frequent in sheltered sites and wallaby grasses (*Danthonia spp.*) three awned speargrasses (mainly

Aristida vagans), spear grasses (*Stipa spp.*, particularly *Stipa nervosa* var. *nervosa*) and short haired plume grass (*Dichelachne sciurea*) and loves grasses (*Eragrostis brownii* and *E. phillipica*) more common in more exposed places. Some species show a wide range of tolerance along this spectrum, the wiry panic being one of the few grasses able to grow on exposed bare soils and yet able to tolerate the dense shade about a substorey of ti-tree whilst short-haired plume grass is almost ubiquitous. But many sites are too disturbed for these adaptations to have sorted the grasses out. *Themeda australis* and *Stipa nervosa*, for example, persist as constituents of the sward in shady woodlands though they seem unable to flower. Stands of *Microlaena stipoides* and *Entolasia marginata* cansurvive in neat circles about the stumps of cut ti-tree in open glades or as larger stands in areas of felled and cleared scrub, somewhat thinned and weakened it is true and unable to flower freely or grow well in dry seasons and therefore susceptible to being invaded, often by exotics such as *Paspalum dilatatum*, *Lotus angustissimus* and *Scutellaria racemosa*. More usually, the few herbs that occur in these swards are natives such as *Dichondra repens*, *Polymeria calycina*, *Hardenbergia violacea*, *Brunoniella australis*, *Viola betonicifolia*, *Lobelia alata*, *Scaevola albida*, *Myoporum debile*, *Tylophora barbata*, and even the maiden hair fern (*Adiantum aethiopicum*). But all are far more common where the grasses are sparsest.

The understorey of shrubs and tall herbs in the lower woodlands include a number of shade tolerant or moisture seeking species, many of them having seeds that are probably spread bybirds. The cheese tree (*Glochidion ferdinandi*), *Omalanthus stillingiifolius*, the pittosporums (*Pittosporum undulatum*, *P. revolutum*), the lantana (*Lantana camara*), the privets (mainly *Ligustrum sinense*) are some of the less successful colonists; *Breynia oblongifolia*, *Phyllanthus gasstroemii*, *Asparagus officinalis*, *Myrsiphyllum asparagoides*,, *Rapanea variabilis*, *Notoleaalongifolia* with their ability to survive or even multiply after fires by suckering are some of the more successful ones. However, shrubs with a wide range of tolerance may establish, many of them being fire weeds and plants of the scrubs and exposed places such as the wattles, *Pimelea linifolia*, *Helichrysum diosmifolium*, *Olearia microphylla*, *Pultenaea villosa*, *Daviesia ulicifolia*, *Indigofera australis*,, the hop bush (*Dodonaea triquetra*) and even occasional *Cassinia arcuata*. Usually such plants are scattered specimens but in a few places on Duck River that appear to have been fire free some of them have built up into a dense substratum of shrubs beneath the eucalypts. One such stand is a mixture some 5-6ft high of hopbush, Dillwynia, Helichrysum with occasional Epacrids. Others include small stands of species that elsewhere are only occasional plants in the scrubs, the one population of the fire-sensitive *Lasiopetalum parviflorum* having been built up by seedcarried by flows of water, others of *Rulingia pannosa* apparently being less ephemeral as the species both seeds prolifically and suckers from its rootstocks after fire. However, fires seem to have been too frequent in most places for a continuous low stratum of shrubs to form. Probably constant burning has also gradually reduced the remnants of an older, tall shrub and low tree stratum to isolated specimens, the kurrajong (*Brachychiton populneum*), forest oak (*Casuarina torulosa*), black she-oak (*Casuarina littoralis*) and the dogwood (*Jacksonia scoparia*) being on the verge of extinction. However, the native cherry (*Exocarpus cupressiformis*) regenerates well though there are only a few mature specimens.

The composition of the dominants in the woodlands and scrubs has also been altered, probably mainly by fire, and in ways other than the the obvious bias towards Melaleucas at the expense of the trees. The two dominant species in the original grey box-broad leaved ironbark (*Eucalyptus moluccana-E. fibrosa*) association are also the last to mature into fruiting specimens and are, at some stages in their growth, among the most fire sensitive specimens. Thus a single fire either killed outright many stems of these species of a thickness less than 10cm. DBH or reduced them to lignotubers whilst most of the red mahogany (*E. resinifera*) and the woollybutt (*E. longifolia*) survived, the crowns of the woollybutt usualling being the ones least damaged. The broad-leaved ironbark is nonetheless well represented in most stands since the stems of a slightly larger girth have more insulation between the cambium and the deep furrows in the bark that seem to be the Achilles heel of the young saplings. But stems of the grey box remain susceptible to severe fire damage much longer and, once cut back to a lignotuber or stump, most specimens have great difficulty in rebuilding a crown now fires are so common despite the rapid increases in height they can make. In the scrubs at Rookwood there are now only several stems left. In those at Duck River there are many more but very few are fruiting specimens. A careful check over three years of the stand at the southern end of the Rosneath Golf Course and a more cursory one of part of that on the west bank suggests that the grey box does not flower until it is about twenty five feet high and then only indifferently, if at all, unless the crown is healthy, vigorous, well-developed and free from much competition. Only specimens with a girth of roughly 18-24" DBH or more and with good crowns from 40-60ft high (but again in open situations) seem to flower and fruit well but then do so so prolifically and with such a fine indifference to the state of the season that this must be one reason for the original dominance of the species. The broad-leaved ironbark seems much more of a sporadic bloomer with the size of the crop of blossom, if any, probably dependent more on the status of the site and the health of the individual stem than the state of the season. However, there seems to be a scatter of specimens with crowns that may have, or soon will have, the potential to flower and others that may be recent regeneration and not simply degenerate lignotubers. But I cannot fairly say after three years of searching that I have seen seedlings of the grey box (which, interestingly, proved difficult to grow in the nurservy as they are

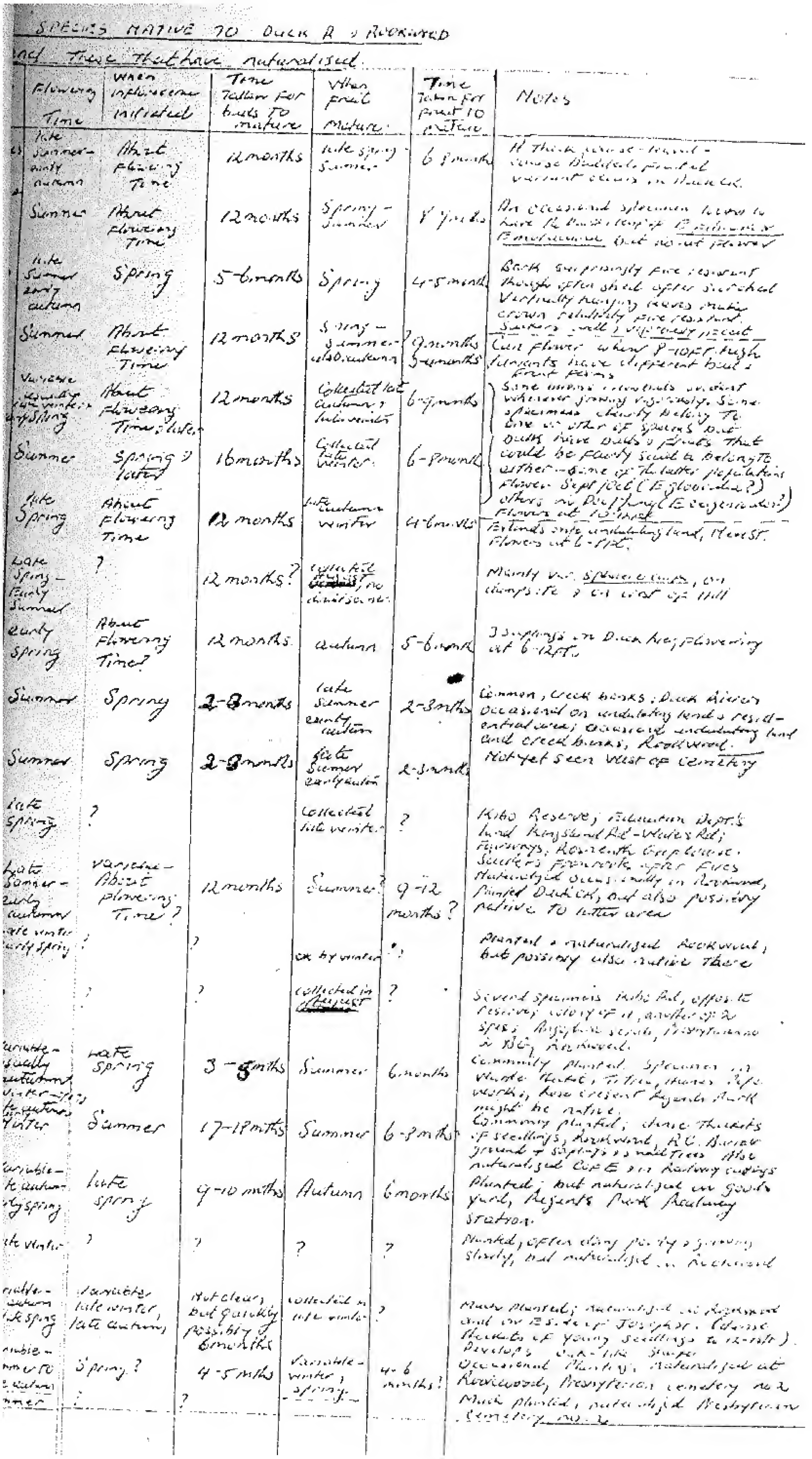


are susceptible to attack by mildew).

The shift to tree species which are quick to mature and fruit or have fire resistant barks has probably most favoured the Angophoras which are becoming dominants in some places, *Angophora floribunda* along the banks of Duck River and *Angophora bakeri* on moist drainage lines in the Presbyterian burial ground. Both species have a striking ability to colonise exposed sites, to quickly build up lignotubers, to sucker profusely after fires, to form stems that are soon protected by fire-resistant bark, are able to flower and fruit at heights of only five to eight feet, and set mature seed within four to six months. The turpentine (*Syncarpia glomulifera*) and red mahogany (*E. resinifera*) though not sowell endowed (see table over) nonetheless are sufficiently fire resistant to have become two of the most common tree species at Rookwood, the turpentine perhaps being the more common because of its ability to sucker from the root system and form thickets once the mainstem is damaged. The woollybutt (*E longifolia*) also has a surprisingly fire-resistant crown and bark and these attributes as well as a rapid rate of growth, particularly when the tree is cut, and an ability to flower when young have helped the species become more common on Duck River than it probably once was. More fire-sensitive species such as the stringybarks (*E. eugenioides*, *E. globoidea*) and the red gums (*E. amplifolia*, *E parramattensis*, *E tereticornis*) seem nonetheless to have been able to increase their numbers because they are quick to mature and bloom prolifically, the stringybarks once their foliage is mature at heights of about 10-12 feet, the gums somewhatsooner at even 6-8ft., and because their seedlings seem well able to establish on difficult sites such as bare subsoils or grasslands. Adaptations of this sort which no doubt once helped them compete with the box and ironbark seem now to allow themto multiply at the expense of those species, particularly the grey box.

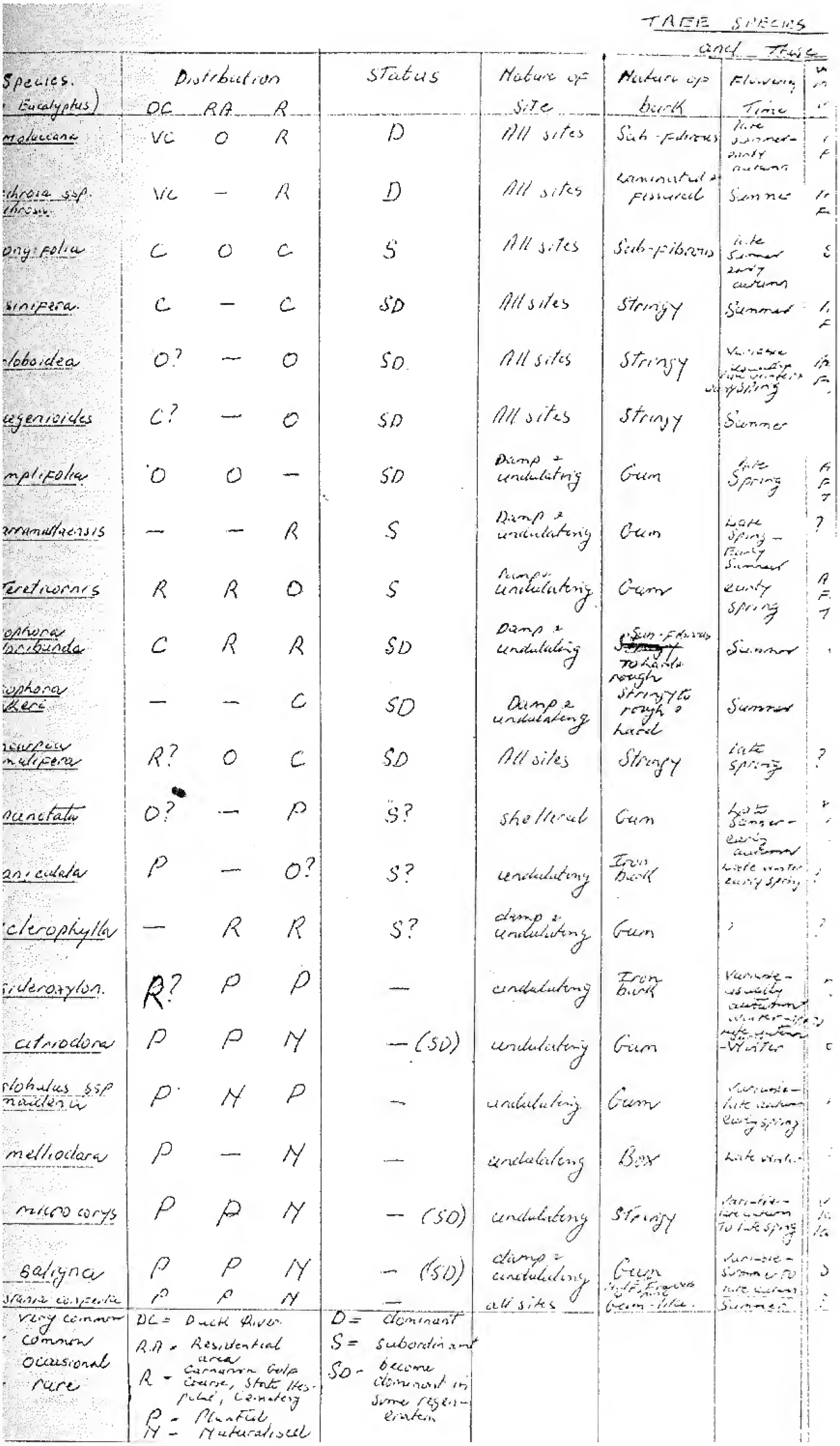
(2) Tall woodlands

Both sample areas have been so long cleared of their original vegetation that even the best stands of trees such as those about the Hillston property on Duck River are regrowth. But the fragmentary evidence provided by regeneration of this sort and by the few veteran eucalypts elsewhere suggests that both were once areas of tall woodlands or dry schlerophyll forests some 60-80ft. high in which the dominants were species of the drier clay soils of the Sydney Basin, the grey box and broad-leaved ironbark. (An *E moluccana*-*E fibrosa* association) However, their assoc~~aitions~~iates were both species of the drier areas such as *E longifolia*, *E tereticornis*, *E.eugenioides*, species of



SPECIES NATIVE TO DUCK R & ROOKWOOD
and those that have naturalised.

Flowering Time	When inflorescence initiated	Time taken for buds to mature	When fruit mature	Time taken for fruit to mature	Notes
late summer–early autumn	About flowering time	12 months	late spring–summer	6 months	[illegible] variant occurs in Duck Ck.
Summer	About flowering time	12 months	Spring–summer	8 months	An occasional specimen seems to have the bud [illegible] of E. [illegible] or E. [illegible] but do not flower
late summer early autumn	Spring	5–6 months	Spring	4–5 months	Bark surprisingly fire resistant though often shed after scorched. Vertically hanging leaves make crown relatively fire resistant. Suckers well & vigorously recover
Summer	About flowering time	12 months	Spring–summer also autumn	9 months 3 months	Can flower when 8–10 ft high. Juveniles have different bud & fruit forms
Variable usually late winter early spring	About flowering time; later	12 months	Collected late autumn, late winter	6–9 months	Some unusual individuals [illegible] wherever growing vigorously. Some specimens clearly belong to one or other of species but others have buds & fruits that could be fairly said to belong to either – some of the latter populations flower Sept/Oct (E. globoidea?) others in [illegible] (E. [illegible]?) Flowers at 15 [illegible]
Summer	Spring & later	16 months	Collected late winter	6–9 months	
late Spring	About flowering time	12 months	late autumn winter	4–6 months	Extends onto undulating land, Mare St. Flowers at 6–8 ft.
Late spring – early summer	?	12 months?	collected ~~[illegible]~~, no [illegible]		Mainly var. [illegible], on [illegible] & on west of hill
early spring	About flowering time?	12 months	autumn	5–6 months	3 saplings on Duck Ck; flowering at 6–12 ft.
Summer	Spring	2–3 months	late summer early autumn	2–3 months	Common, creek banks; Duck River. Occasional on undulating land & residential area; occasional undulating land and creek banks, Rookwood.
Summer	Spring	2–3 months	late summer early autumn	2–3 months	Not yet seen west of cemetery
late spring	?		collected late winter	?	Kibo Reserve; Education Dept's land Kingsland Rd – Wales Rd; Fairways, [illegible]. Suckers from roots after fires
Late summer – early autumn	variable – About flowering time?	12 months	Summer?	9–12 months?	Naturalised occasionally in Rookwood, planted Duck Ck, but also possibly native to latter area
late winter early spring	?	?	[illegible] by winter	?	Planted & naturalised Rookwood, but possibly also native there
	?	?	collected in August	?	Several specimens [illegible] Rd, opposite reserve; [illegible] of it, another of 2 [illegible], [illegible], Presbyterian [illegible], Rookwood.
Variable – usually autumn	late spring	3–5 mths	Summer	6 months	Commonly planted. Specimens in [illegible] Park, [illegible], might be native.
winter–spring [illegible] autumn, winter	Summer	17–18 mths	Summer	6–8 mths	Commonly planted; dense thickets of seedlings, Rookwood, R.C. burial ground & saplings & small trees. Also naturalised [illegible] Railway cuttings
Variable – late autumn – early spring	late spring	9–10 mths	Autumn	6 months	Planted but naturalised in goods yard, Regents Park Railway station.
late winter	?	?	?	?	Planted, often dying partly & growing slowly, but naturalised in Rookwood
variable – autumn – late spring	variable: late winter, late autumn	Not clear, but quickly, possibly 6 months	collected in late winter	?	Much planted; naturalised at Rookwood and on E side of Joseph St. (dense thickets of young seedlings to 12 ft). Develops oak-like shape
variable – summer to autumn	Spring?	4–5 mths	Variable – winter, spring	4–6 months!	Occasional planting; naturalised at Rookwood, Presbyterian cemetery no 2
summer	?	?			Much planted, naturalised Presbyterian Cemetery no 2



TREE SPECIES
and Thei

Species. (Eucalyptus)	Distribution DC	RA	R	Status	Nature of Site	Nature of bark	Flowering Time
moluccana	VC	O	R	D	All sites	Sub-fibrous	late summer-early autumn
brosa ssp. brosa	VC	—	R	D	All sites	Laminated & fissured	Summer
ongifolia	C	O	C	S	All sites	Sub-fibrous	late Summer early autumn
sinifera	C	—	C	SD	All sites	Stringy	Summer
globoidea	O?	—	O	SD	All sites	Stringy	Variable depending on winter or spring
eugenioides	C?	—	O	SD	All sites	Stringy	Summer
mplifolia	O	O	—	SD	Damp & undulating	Gum	late Spring
parramattensis	—	—	R	S	Damp & undulating	Gum	Late Spring – Early Summer
Tereticornis	R	R	O	S	Damp & undulating	Gum	early spring
ophora floribunda	C	R	R	SD	Damp & undulating	~~Stringy~~ Sub-fibrous to hard rough	Summer
ophora bakeri	—	—	C	SD	Damp & undulating	Stringy to rough & hard	Summer
ocarpa mmifera	R?	O	C	SD	All sites	Stringy	late spring
unctata	O?	—	P	S?	sheltered	Gum	Late Summer – early autumn
aniculata	P	—	O?	S?	undulating	Iron bark	late winter early spring
clerophylla	—	R	R	S?	damp & undulating	Gum	?
ideroxylon.	R?	P	P	—	undulating	Iron bark	Variable – usually autumn winter–spring
citriodora	P	P	N	—(SD)	undulating	Gum	late autumn -Winter
lobulus ssp maidenii	P	N	P	—	undulating	Gum	Variable – late autumn early spring
melliodora	P	—	N	—	undulating	Box	Late Wint..
microcorys	P	P	N	— (SD)	undulating	Stringy	Variable – late autumn to late spring
saligna	P	P	N	— (SD)	damp & undulating	Gum	Variable – Summer to late autumn
stania conferta	P	P	N	—	all sites	half fibrous gum-like	Summer
very common common occasional rare	DC = Duck River RA = Residential area R = Carnarvon Golf Course, State Hospital, Cemetery P = Planted N = Naturalised			D = dominant S = subordinant SD = become dominant in some regeneration			

wetter areas such as *Angophora floribunda* and *E.resinifera* and species of the sandstone soils and their ecotones such as the ~~xx~~ *Angophora bakeri*, the grey gum (*E. punctata*) and the scribbly gum (*E. sclerophylla*).

The structure of the original vegetation is least in doubt for all that most of the verteran eucalypts have the small butts and much branched and spreading crowns of open woodland trees that have always been free of much competition throughout lifetimes that must be of at least one hundred years to judge from the yardstick of the eight grey box and their three offspring about 296 Park Road - at least fifty years in the growing at a little over a foot a year and fifty years in which their height and contour are known to have changed but little. But remnants of this sort are probably atypical. Wherever competition among the trees has been fierce, as it has been on parts of the Hillston property, the form of the dominants in the stand has become that of forest trees with long slender butts and shallow small crowns whilst that of the remaining closely spaced specimens is of long slender, scarcely branched poles. Competition has also forced many of the box and ironbark on the west bank of Duck River to adopt much the same growth habit though these specimens,of course, are far from being the sixty to eighty feet high of the older stands of box on the Hillston property and the ironbarks in the State Hospital grounds.

The composition of the original stands of eucalypts is more of an open question but in the least disturbed regeneration on Duck River the grey box and broad leaved ironbark are usually dominant. Eastwards of the river both species are also well represented among the occasional veterans that survive in parks and gardens and no doubt the *E. moluccana-E fibrosa* association once extended into the very disturbed scrubs at Rookwood, as it still does into the low woodlands to the south at Potts Hill, for all that there now seem to be only two grey box in the areas of the cemetery examined. Probably many of the subordinant tree species were also ~~xx~~ once scattered indiscrimminantly throughout thewhole area as the woollybutt, red mahogany, two stringybarks and the rough barkedapple still area. But nowadays some species seem to survive by chance in one area and not in the other. The three species of red gum, for example, grow on sites not obviously different from one another yet *E parramattensis* is an occasional tree in Rookwood and one that is found to the west about Fairfield but does not now at least (see Maiden) seem to grow on Duck River where the common red gum is*Eamplifolia* (a species that seems absent from Rookwood) and where there are now only three sapling forest red gum (*E tereticornis*) though this species is common enough in the cemetery. The turpentine (*Syncarpia glomulifera*),like the forest red gum,extends westwards along theridge from Rookwood towards the southern railway line but survives only in the shrubberies between the fairways on the Rosneath Golf course on Duck River. More open to doubt are the status and former distribution of the trees which normally are species of sandstone areas and their ecotones. The narrow-leaved apple (*Angophora bakeri*) and the small stand of scribbly gum (*E. sclerophylla*) at Rookwood are probably natives that are part of the remnants of a sandstone flora there, with the scribbly gum perhaps also occurring near the Albo reserve with turpentine, forest red gum, rough barked apple and box. But the two small stands of the grey gum in the heart of the low woodlands on the west bank of Duck River are puzzling, to say the least, but look to be the peers of the other native tree species, are in an area where no one would have reason to plant them, and therefore must be tentatively looked on as an unusual occurrence of this, the most fire-sensitive of all the species collected that survives in this one, sheltered spot. Grey ironbark (*E. p aniculata*) may also have once been native to Rookwood but has been so much planted there and then naturalised that its status must remain an open question. Other eucalypts to have naturalised at Rookwood are more obviously exotics, some having established only a few specimens (the blue gum, *E. saligna*, the grey gum, *E punctata*, the yellow box, *E melliodora*) whilst others are sufficiently invasive to form dense thickets, the tallowood (*E. microcorys*) mainly in the horse paddocks at the State Hospital and the lemon scented gum (*E. citriodora*) in old burial grounds and even railway cuttings. But the very success of these species, nonetheless,is a nice comment on the status of the sites as ones able to support forest trees tolerant of clay-based soils.

The interpretation put forward here differs fromthat ~~xx~~ of Kartzoff (*Nature and a city*) who suggests that the 'high forest' of blackbutt and Sydney blue gum (an *E. pilularis-E. saligna* association) may have extended as far west as Merrylands and Granville. Certainly some of the species within that association as he lists them are present - the turpentine, the rough- barked apple, the red mahogany, the white stringybark, the grey gum and the scribbly gum. But most, other than those of the the sandstones and their ecotones, are ~~[illegible]~~ given by Alma Pidgeon as being species of the 'shales' of 'the Cumberland Basin' and are quite consistent with the 'forest types' and 'subsidiary species' she recorded for the 'Bankstown-Liverpool District' (Table 10, page 152 of article in bibliography). The area, no doubt is transitional both in the amount of rainfall it receives and the proportion of its soils derived from sandstones particularly along the ridge towards Potts Hill where so many of the remnants of the original vegetation are. But the box and ironbark are dominant in the least distrubed regeneration, they are the species best suited to the soils and have slender quick growing habits of growth that would make them competitive with any of Kartzoff's'forest trees' - indeed, the ironbark in the nursery is surprisingly tolerant of shade, has the leaf disposition and form of 'forest' trees such as *E paniculata*, and the veterans on Joseph Street with girths up to five to seven feet are among the most massive and impressive trees in the district. Probably, therefore, it is not unreasonable to assume the *E moluccana-fibrosa* association, or a variant of it in which forest red gum was an important ~~XXXXXXX~~ component, extended as far east as Homebush. Perhaps the grey box is near to its eastern limits here particularly if it is susceptible to 'wet feet' as Kartzoff suggests. But the 'stagginess' he thinks to be indicative of this weakness is mainly found in older specimens, not vigorous and healthy younger ones, and may be a complex phenomenon in a species that in old age seems more dependent on forming new growth as laterals off massive limbs rather than the extension of the main leaders and which seems very susceptible to pruning by cold southerlies - for the species is also near its southern limits in the County of Cumberland and some exposed species have quite russet foliage by the end of winter. Nor is the Box the only species that seems to adapt with difficulty to clearing and disturbance, many specimens of *E. eugenioides* being equally staggy with diverted street drainage suspect as one possible cause. But I can offer no explanation for the failure of the oldest stand of *E. fibrosa* in the State Hosptial grounds other than old age or [illegible], for the almost general decay among many planted specimens of *E. botryoides*. Indeed, the only two native tree species obviously affected by the ebb and flow of the seasons these past three years have been the cabbage gum and the wollybutt, the hailstorm and the dry spring and early summer of 1976/7 having almost totally destroyed the developing infloresences of both species and finally killed off several failing specimens of the cabbage gum.

The one stand of regenerated trees that is almost a tall woodland has been included in the Rosneath Golf course and has as a substorey a few scattered *Melaleuca decora* and a ground cover of exotic and native grasses and ground herbs that are regularly mowed.

V. The Future

Those stands of bushland that have not been made natural reserves probably have little or no future. In the cemetery the largest area of scrub is sandwiched between the Anglican and Catholic burial grounds, the two that are being most actively extended to cope with Sydney's much larger, ageing population. The Crematorium management, apparently anxious to establish its boundaries, has surveyed and begun extending walls towards the heath-like low scrub to its west. The areas of scrub and grassland in the Presbyterian, Wesleyan and Independent burial grounds are the least needed but also at risk because the grounds seem to be developed and bulldozed haphazardly rather than systematically. On Duck River, Auburn council is about to begin to turn the scrub on the east bank south of Everley Road into playing fields and the Hillston property, now held on a life occupancy, will soon revert to council.

The low woodland, scrubs and grassland on the west bank of Duck River north of the intended playing fields on the north side of Everley Road has been reserved as natural bushland. But there are no rangers, cutting of trees and burning off is indiscriminate and the better areas of woodland to the south are gradually being opened up to vehicles so that stolen cars may be the more discretely stripped and burned and the circuit for mini-bike riders extended. If Parramatta Council were to open up the riverside walk that was to be made when Auburn council received its grants to build a Botanic Gardens on the river just north of Chisolm Road vandalism of this sort might be checked during the day. However, as the stand may soon have the only examples of most of the different habitats, types of vegetation (other than Kunzea scrub and tall woodland), and many of the species representative of the disturbed vegetation in the Auburn area, a more active form of management is probably desirable. Since the area is a reserve, it has to remain open to the public and probably to vehicles. Parramatta council's efforts to close off Beverley Road failed and were, in anycase, somewhat pointless as vehicles have always had access to the park from Wellington Road. But were rangers (council apparently has some) to visit the area after 3 p.m. weekdays, during schoolholidays and at weekends much vandalism could be checked. Fires would still occur and probably it is desirable that theyshould on a small andcontrolled scale to avoid a crown fire that could destroy the area of low woodland. But fires need to be less frequent than they are if the vegetation is not to be damaged and if it is to be attractive enough for people to use the riverside walk. Perhaps the best compromise would be to use fire as a tool of management, burning a mosaic of small areas over several seasons and using the many paths as checks to cool grass fires. Burning in late winter or early spring might give a better regeneration of seedlings. Such a programme could possibly be worked in with one to re-introduce native plants of the sort that Baulkham Hills Shire Council is experimenting with in reserves at Carlingford.

The areas of tall woodland and the trees on the Hillston property probablywill probably survive best if included in the Auburn Municipal Golf Course.

VI. The species collected

Of the 568 species collected (representative of 101 families) 292 (51%) seem to have been native to a district in which the clay-based soils nonetheless carry the remnants of a sandstone flora, particularly about Rookwood. Included among the 276 exotics are a number of Australian species. (see tables on next page).

Ten families include some 312 (55%) of the species collected, those being best represented being the Gramineae, Compositae, Papilionaceae, Myrtaceae and Mimosaceae. The latter three families, no doubt, would be well represented in most samples of Australian vegetation other than those made in rainforests. Monocotyledonous familes are particularly well represented partly because the soils favour the growth of grasses, sedges and rushes, partly because a number of species, particularly orchids

Table - Families with most species

Family	No. of species Total	Natives	Exotics	Family	No. of Species Total	Natives	Exotics
Gramineae	93	44	49	Liliaceae	13	8	5
Compositae	50	22	28	Cruciferae	12	1	11
Papilionaceae	44	21	23	Euphorbiaceae	10	7	3
Myrtaceae	40	31	9	Orchidaceae	9	9	-
Mimosaceae	16	12	4	Xanthorrhoeaceae	7	7	-
Iridaceae	16	1	15	Amaryllidaceae	7	-	7
Cyperaceae	15	13	2	Chenopodiaceae	8	6	2
Juncaceae	13	3	10	Caryophyllaceae	7	1	6

Table

Distribution of indigenous and exotic specie s between the major taxa

	No of Families	No. of Species Total	Indigenous	Exotic	No. of Species on Duck R. Total	Indig-enous	Exotic	No. of Species only at Rookwood Total	Indig-enous	Exotic
PHYTA	2	4	3	1	3	3	—	1	—	1
SPERMAE	3	5	—	5	—	—	—	5	—	5
SPERMAE LEDONES	79	376	201	175	311	168	143	65	33	32
COTYLEDONES	17	183	88	95	144	67	77	39	21	18
	101	568	292	276	458	238	220	110	54	56

Table

Distribution of species among the families

No of species 1	2	3	4	5	6	7	8	9	10	11 - 20	21 - 30	31 - 40	41 - 50	over 50
[illegible]	18	16	7	2	4	3	2	3	1	6	—	1	2	1

have survived at Rookwood where the land probably has not been grazed for a long time, and partly because of the number of bulbs that have naturalised.

The native species listed are recorded by Beadle *et alia* as being adapted to habitats that range from wet schlerophyll forests through to the dry parts of the Cumberland Plain but are mainly those that could be expected to be growing in the area. Many of those adapted to the moister environments tend to have a limited distribution (*Tylophora barbata*, *Pittosporum undulatum*, *Glochidion ferdinandi*, *Pandorea pandorana*) or to be represented by solitary specimens or colonies (*Parsonia straminea*, *Oplismenus imbecillis*). But others are common (*Breynia oblongifolia*) or occur indiscriminately in most habitats (*Notolaea longifolia*). The native species recorded by Beadle *et alia* as normally growing on sandstone soils andtheir ecotones are best represented in Rookwood where a number of species occur that appear not to be growing on Duck River. (see appendix II). Other species are found in both places or on Duck River only (e.g. *Eucalyptus punctata*, *Asterolasia correifolia*, *Pultenaea retusa*, *Pomaderris lanigera* and *P. ferruginea*).

The exotic species among the Australian natives are mainly garden plants that have naturalised (*Melaleuca armillaris*, *M. quinquenervia*; *Eucalyptus citriodora*, *E. globulus ssp. maidenii*, *E melliodora*, *E.microcorys*, *E. saligna*; *Tristania conferta*; *Acacia podalyriifolia*, *A.pycnantha*, *A. saligna*). The exotics from outside Australia include many of the species likely to establish in a closely settled area of Sydney with clay soils. However, a number that are invasive weeds in the moister environment of the garden here have difficulty in establishing in much of the bushland (*Cinnamomum camphora*, *Pittosporum undulatum*, *Ligustrum lucidum* and *L. sinense*, *Ochna serrulata*). Unusual distributions include the ice weed (*Aptenia cordifolia*) at the base of the eucalypts at the southern end of Rosneath Golf Course; *Gnaphalium candidissimum* and *Hydrocotyle bonariensis* on moist drainage lines at Rookwood; *Suaeda australis* beneath pine trees at Rookwood; the number of South African bulb species that have naturalised in thecemetery, particularly *Watsonia bulbifera* which is an invasive weed there and may become one on Duck River.

Roughly 115 species were collected at Rookwood that do not seem to grow on Duck River. Of these eleven were tree and palm species (*Pinus* spp., *Araucaria* sp., *Eucalypt* spp., *Tristania* sp., *Phoenix* sp.) that have been able to naturalise because the area is a cemetery; eight were South African bulbs found there for the same reason; twenty five normally grow on soils derived from sandstones andtheir ecotones; some of the orchids, rushes, sedges and sedge-like plants (thirteen species) may occur there because the area has not beengrazed for many years.

Many species are listed as occurring only on Duck River but these may well be present in Rookwood as I have only collected there from September to mid November, 1978 but have spent much time over three years collecting on Duck River.

Appendix I - List of Species

Nomenclature is as in N.C.W. Beadle et alia, Flora of the Sydney Region, 1972 edition, if the species is listed in that text; the relevant page number is given in brackets. Other Eucalyptus species are cited as by Johnston and Marryatt, appendix to W.F. Blakely, A Key to the Eucalypts, 3rd. ed., 1955. Other species have been identified from a variety of works such as J.M. Black, Flora of South Australia. I had access to no satisfactory flora for South Africa and have used the Keys in the Oxford Dictionary of Gardening and L.H. Bailey's Manual of Horticulture.

Many species, particularly those with unusual distributions, have been identified for me by the botanists of the National Herbarium of the Royal Botanic Gardens Sydney.

Plant families within the major taxa and their subdivisions have been arranged alphabetically for my own convenience. Naturalised species are marked with an asterisk. Plants shown in brackets were found as seedlings in the bush but have not naturalised and were not included when the tables in the text were drawn up.

The distribution of the species through the different micro-environments referred to in the text and the frequency with which species occur, if known, has been shown by the following symbols

C - Rookwood Cemetery, State Hospital Grounds, Carnarvon Golf Course, Kibo Reserve, waste land belonging to the Education Department, Kingsland and Waters Road (ie. east of the main southern railway)
D - Duck River; rarely, west of the southern railway
1 - Low woodland, Duck River
2 - ti-tree and eucalypt scrub
3 - grasslands
4 - exposed soils and subsoils
5 - drainage lines and edges of permanent sheets of water, creeks etc.
6 - permanent and transient sheets of water
7 - graves, Rookwood Cemetery
8 - dumped soil, edges of roads, tracks

A - common
O - occasional
R - rare (one to several specimens seen)

The tables in the last section of the text, for want of time, were drawn up from a rough draft of this appendix and therefore probably don't agree exactly with it. However, the differences aren't such that they would change the argument in the text.

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	C	D	1	2	3	4	5	6	7	8
PTERODOPHYTA										
ADIANTACEAE										
Adiantum aethiopicum L. (69)		X	R				X			
Cheilanthes tenuifolia (Burm.f) Sw. sens. lat. (71)	X	X	X	X	O					
Pellaea falcata (R. Br.) Fee var. falcata (70)		X					R			
DENNSTAEDTIACEAE										
Pteridium esculentum (Forst. f) Cockayne	R	O					[illegible]		R	
OLEANDRACEAE										
xNephrolepis cordifolia (L.) Presl. Jones and Clemesha, Aust. Ferns, 226	R						R			
GYMNOSPERMAE										
ARAUCARIACEAE										
xAraucaria bidwillii Hook.	R								R	
(Araucaria columnaris (Forst~~er~~) Hook.)	R									
PINACEAE										
xPinus halepensis Miller	O								O	
xPinus pinaster Sol. Ex Ait. (96)	O								O	
xPinus pinea L.	O								O	
xPinus radiata Don (96)	O								O	
ZAMIACEAE										
Macrozamia spiralis (Salisb.) Miq. (96)	O	O	O	O	O					
ANGIOSPERMAE										
DICOTYLEDONES										
ACANTHACEAE										
Brunoniella australis (R. Br.) Bremek.		X	X							
Brunoniella pumilio (R. Br.) Bremek. (504)		O	O							
AIZOACEAE										
xAptenia cordifolia (L.) Schwantes (130)		O	O							
AMARANTHACEAE										
Alternanthera denticulata R.Br. (196)		O						[illegible]		
xAlternanthera philoxeroides (Mart.) Griseb. (196)		X						X		
Amaranthus hybridus L. sens. lat.		O								O
ARALIACEAE										
Polyscias sambucifolia (Sieb. ex DC.) Harms (391)	O	O	O	O	R					
APOCYNACEAE										
xNerium oleander ~~(L.)~~ (Black, IV 695)		R			R					
Parsonsia straminea (R.Br.) F. Muell. (416)		R					R			
x Vinca major L. (417)	O								O	
ASCLEPIADACEAE										
xAraujia hortorum Fournier (419)	O	O	O	O	O		O			
Tylophora barbata R. Br. (419)		O	O							

BIGNONIACEAE	C	D	1	2	3	4	5	6	7	8
Pandorea pandorana (Andr.) Steen (502)		O	R				O			
x Campsis x Tagliabuana		R								
BASELLACEAE										
xAndredera cordifolia (Ten.) Steen (197)		X					X	[illegible]		
BORAGINACEAE										
(Myosotis sylvatica)		R								R
CACTACEAE										
xOpuntia stricta (Haw.) Haw. (235)		R					R	[illegible]		R
CAESALPINIACEAE										
xCassia coluteoides Coll. (277)	R	R					R	[illegible]		R
CAMPANULACEAE										
Wahlenbergia communis Carolin (434)	X	X	X	X	X	O				
Wahlenbergia gracilis(Forst. et f.) Schrad. (434)	X	X	X	X	X					
Wahlenbergia stricta Sweet (434)		R		R						
CAPRIFOLIACEAE										
xLonicera japonica Thunb. (429)	O	X					X			
(Abelia x grandiflora)		R								
CARYOPHYLLACEAE										
xCerastium glomeratum Thuill. (175)		O			O					
xPetrorhagia nanteuilii (Burnet) Ball et Heywood (177)	X	X		X	X					
xPetrorhagia velutina (Guss.)Ball et Heywood (177)	O	X		X	X					
Polycarpon tetraphyllum (L.) L. (177)		O	O							
xSilene anglica L (178)	X	X			X					
XParonychia brasiliana DC. (178)	O									O
xSpergularia rubra (L.) J.etC.Presl. sens.lat. (177)	O	O					O			
xStellaria media (L.) Vill. (176)		O					O			
CASSYTHACEAE										
Cassytha glabella R. Br. (152)	X			X						
Cassytha paniculata R. Br. (152)	X	X		X						
CASUARINAXCEAE										
(Casuarina cunninghamiana Miq.)										
Casuarina glauca Sieb. ex Spreng.(353)	X	O					X			
Casuarina littoralis Salisb. (352)	R			R						
Casuarina torulosa Ait. (352)	R	R	R	R						R
CHENOP ODIACEAE										
xChenop odium album L. (192)	O	O		O						
Chenopodium polygonoides (Murr.) Aellen		O	O							
Chenopodium trigonon Roem. et Schult.	O	O				[illegible]	O			
Dysphania littoralis R. Br. (194)		O				O				
Rhagodia hastata R. Br. (192)	O	X	X	X						
Rhagodia nutans R.Br.		O		O						
Suaeda australis (R. Br.) Moq.	R									R
CELASTRACEAE										
Maytenus ~~MAYTENUS~~ cunninghamii (F. Muell.) Loes. (360)	X	X	O	X						

COMPOSITAE	C	D	1	2	3	4	5	6	7	8
xArtemisia vulgaris L. (465)		X					X			
xArctotheca calendula (L.) Levyns	X	X								X
xAster subulatus Michx. (457)		X								X
xBidens subalternans DC (460)		O					O			
xBidens pilosa L. (460)	X	X	O	O			X			
Calotis cuneifolia R. Br. (453)	O	X								X
Calotis lappulaceam Benth		O			O					
Brachycome angustifolia A. Cunn. ex DC. var. angustifolia		O	O							
Cassinia arcuata R. Br. (471)	X	X	R	O		X				
Centipeda minima (L.)A. Br. et Aschers. (463)		O					O			
xChrysanthemoides moniliferum (L.) T. Nore Nore. (469)	X	O		X					X	
xCichorium intybus L. (478)		R								R
xCirsium vulgare (Savi) Ten. (476)	O	O		O			O			O
xCoreopsis lanceolata L. (461)	X			O	X				X	
Cotula australis (Sieb. ex Spreng.) Hook. f. (463)	X	X		O	X					X
Cotula coronopifolia L (462)	X	X					X			
xErigeron bonariensis L. (457)	O	O	O	O		O				O
xErigeron floribundus (H.B.K.) Sch. Bip.	O	O						O		O
xEupatorium adenophorum Spreng. (450)	O	O		O			O			
xFacelis retusa (Lam.) Sch. Bip. (471)	O	O	O	O						
XGnaphalium candidissimum Lam. (470)	X						X			
xGnaphaliumluteo-album L.	X	X	O	O	X					X
xGnaphalium japonicum Thunb.	X	X	O	O	X					
xGnaphalium purpureum L.	X	X	O	O	X					
xGnaphalium spicatum Lam.	R	R								
xHelianthus annuus L.		O					O			O
xHelichrysum apiculatum (Labill.)DC.473	X	X		O	X					
xHelichrysum diosmifolium (Vent.) Sweet	X	X	O	X						
xHelichrysum scorpioides Labill. (475)	X	X		O	X					
Helipterum australe (A.Gray) Druce 473		O								O
xHypochoeris glabra L. (480)	O	O								
xHypochoeris radicata L.	X	X	X	X	X					X
xhypochoeris microcephala (Sch. Bip .) Cabr. var albiflora (O.K.) Cabr.	R					R				
Lagenophora stip itata (Labill.)Druce (451)		X	X							
Olearia microphylla (Vent.) Maiden et Betche (454)	O	X	X	X						
xPicr is hieracioides L.		R								
Senecio hispidulus A. Rich var hispidulus (466)	O	X	X	X			X			
Senecio lautus Forst. f. ex Willd. 468	O	O			O					
Senecio linearifolius A. Rich. (467)		R		R						
Senecio quadridentatus Labill. (466)		O		O						
xSilybum marinanum (L) Gaertn. (477)		R								R
Solenogyne bellioides Cass. var. bellioides 451		O		O						
xSoliva anthemifolia (Juss.)R. Br.ex DC.	O	O								O
XSoliva pterospermam (Juss) Less. (464)	O	O								O

	C	D	1	2	3	4	5	6	7	8
xSonchus asper (L.) Hill (481)	0	0		0						0
XSonchus olearaceus L.	X	X	0	X						
xTragopogon porrifolius L. (479)		R								R
Vernonia cinerea Less. (450)		X	X	X						
Vittadinia muelleri N.T. Burbidge (456)		0				0				
Vittadinia triloba (Gaudich.) DC.		0		0						
CONVOLVULACEAE										
Dichondra repens Forst. et.f. (494)	X	X	X	X	X		X			
XIpomaea incicia (Burm.)Merrill (493)	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0			0
Polymeria calycina R. Br. (494)	0	X	X	X	0	0				
CRASSULACEAE										
?xBryophyllum tubiflorum	R	R					R		R	
xCrassula multicava	R	R					R		R	
Crassula sieberana (Schultes)Druce (473)	R?									R
xSedum praealtum	R	R					R		R	
CRUCIFERAE										
xBrassica fruticulosa Cyr. (163)		0					0			
xBrassica juncea (L) Czernjaew		0					0			
xBrassica rapa L. ssp. campestris (L.) Clapham (163)		0					0			
XCapsella bursa-pastoralis (L.) Medic. (165)		0								0
Cardamine intermedia Hook. (165)		0	0							
xCoronop us didymus (L.)Sm. (167)	0	0								0
xLepidium bonariense L. (166)	0	0			0					0
xRapistrum rugosum (L.)All. (167)	0									0
xRorippa nasturtium-aquaticmm (L.) Hayek (164)		0					0			
xSisymbrium officinale (L.) Scop. (163)		R								R
xSisymbrium orientale L. (162)		R								R
(Alyssum maritimum)		R								R
DILLENIACEAE										
Hibbertia aspera DC. (230)	0	0		0	0	0				0
Hibbertia diffusa R. Br. ex DC. (229)		R		R						
Hibbertia pedunculata R.Br. ex DC.	0	0		0	0					
DROSERACEAE										
Drosera peltata Sm ex Willd. (174)	0	0					0			0
EPACRIDACEAE										
Astroloma humifusum (Cav.) R. Br. (402)	X	0				X				
Leucopogon lanceolatus (Sm.) R. Br. var. lanceolatus (405)	[illegible]	0	[illegible]	[illegible]			0			
Leucopogon juniperinus R. Br. (406)	0	0	0	0						
Lissanthe strigosa (Sm.) R. Br. (404)	X	X		X	X					
Monotoca scoparia (Sm.) R.Br. (404)	R			R						
Epacris purpurascens R.Br. var purpurascens (409)	0			0						

EUPHORBIACEAE	C	D	1	2	3	4	5	6	7	8
Breynia oblongifilia J. Muell. (251)	O	X	X	O						
Euphorbia drummondii Boiss. (247)		O				O				
xEuphorbia peplus L. (247)	R	R								R
xEuphorbia prostrata Ait. (247)		R								R
Glochidion ferdinandi (J.Muell.) F.M. Bailey (251)		R	R							
Micrantheum ericoides Desf. (248)	X			X						
Omalanthus stillingiifolius F.Muell. (253)	R	R	R	R						
Phyllanthus gasstroemii J. Muell.(249)		X	X	X						
Poranthera microphylla Brongn. (247)	X	X	X	X	~~R~~O					
xRicinus communis L. (251)	R	R					R			
FUMARIACEAE										
xFumaria muralis Sond. ex Koch (159)	O	O					O			
GENTIANACEAE										
xCentaurium erythraea Rafn.(421)	X	X		O	X					
xCentaurium tenuiflorum (Hoffm. et Link) ~~Hirsch~~ Fritsch (421)	X	X		O	X					
GERANIACEAE										
xPelargonium aspera Ehr. ex Willd.(202)	R								R	
xPelargonium domesticum L. H. Bailey	R	R							R	R
xPelargonium inodorum Willd. (202)	O	X	X	X						
GOODENIACEAE										
Goodenia bellidifolia Sm (441)	X	X			X					
Goodenia heterophylla Sm. (441)	R			R						
Goodenia hederacea Sm. (441)	X	X		X	X					
Goodenia ovata Sm (441)		R					R			
Goodenia paniculata Sm. (441)	X	X					X			
Scaevola albida (Sm.) Druce (442)		O	O							
HALORAGACEAE										
Haloragis tetragyna (Labill.) Hook.f. (207)	X	O		O	X					
Haloragis villosa Schindler (207)	R				R					
xMyriophyllum brasiliense Cambess.(208)	R							R		
HYPERICACEAE										
Hypericum japonicum Thunb.	O	X	O	O	O					O
LABIATAE										
xLavandula (vera ?)	R								R	
xScutellaria racemosa Pers. (512)		X			X		X			
xStachys arvensis (L.)L. (513)	O	X			X		X			
xMentha X piperita L. var.(511)		O					O			
LINACEAE										
Linum marginale A. Cunn. ex Planch.(198)	O	O			O					
xLinum trigynum L. (198)	X	X		X	X					
xLinum usitatissimum L. (198)		R					R			
LAURACEAE										
xCinnamomum camphora (L.) Nees (152)	O	R			~~R~~O		O		O	O
LOBELIACEAE										
Lobelia alata Labill. (436)	X	X	X	X	R					
Isotoma fluviatilis (R.Br.) F.Muell. ex Benth.		R					R			

LORANTHACEAE	C	D	1	2	3	4	5	6	7	8
Amyema gaudichaudii (DC.) Tiegh. (370)	O	O	O	O						
Dendrophthoe vitellina (F.Muell.) Tiegh.	O	O		O			O			
Muellerina eucalyptoides (DC.) Barlow (371)	O	O	O	O						
LYTHRACEAE										
Lythrum hyssopifolia L. (203)	O	O					O	O		
xLagerstroemia indica	R	R							R	R
MALVACEAE										
xMalva parviflora L. (243)	O	O			O		O			O
XModiola caroliniana (L.) G. Don (243)	O	O			O		O			O
xSida rhombifolia L. (245)	X	X	O	O			O			O
MIMOSACEAE										
xAcacia baileyana F.Muell (273)	R	R		R						R
Acacia brownii (Poir.) Steud ex DC (265)	O	O	O	O		O				
Acacia decurrens (Wendl.) Willd. (273)	O	X	O	O	O	O	O		O	O
Acacia falcata Willd. (268)	X	X	O	X	O	O	O		O	O
Acacia glaucescens Willd. (272)	R	R	R	R	R		R			R
Acacia longifolia (Andrews) Willd. var. longifolia (272)	X	X	O	X	X	O	O		O	O
Acacia longissima Wendl. (271)	R					R				
Acacia myrtifolia (Sm.) Willd. (267)	O								O	
Acacia parramattensis Tindale (273)	X	X	O	X	X		O		O	O
xAcacia podalyriifolia A. Cunn. ex G. Don (267)	R									R
Acacia pubescens (Vent.) R. Br. (274)	O	X	O	X		R				
xAcacia pycnantha Benth. (269)	O				O				O	
xAcacia saligna (269)	X			O	O				X	
Acacia stricta (Andrews) Willd.		R		R						
Acacia suaveolens (Sm) Willd. (270)	R			R						
Acacia ulicifolia (Salisb.) Court (263)	O	O	O	O		O			O	
MORACEAE										
xMorus nigra		R		R						
XMorus alba		R		R			R			
MYOPORACEAE										
Myoporum insulare R. Br. (505)		R	R				R			
Myoporum debile R. Br. (505)		O	O	O						
MYRSINACEAE										
Rapanea variabilis (R. Br.) Mez. (431)	O	O	O	O						
MYRTACEAE										
(Callistemon x citrinus (Curtis) Skeels (346)										
Callistemon linearis DC. (346)	O	O		O	O					
Callistemon pinifolius DC, (346)	O	O		O	O					
Callistemon rigidus R. Br. (355)	O	O		O	O					
Callistemon salignus (Sm.) DC. (345)	R	O	R	R			O			
Kunzea ambigua (Sm.) Druce (344)	X	O				X				
Leptospermum attenuatum Sm. (341)	X	O			X		O		X	
Leptospermum flavescens Sm. (342)	O	O					O			

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MYRTACEAE (cont.)	C	D	1	2	3	4	5	6	7	8
xMelaleuca armillaris Sm. (347)	O	O			O					
Melaleuca decora (Salisb.) Britten	X	X	X	X	O	O	O			
Melaleuca ericifolia Sm. (347)		O					O			
Melaleuca erubescens (Benth.) Otto(346)	O	O		O						
(Melaleuca hypericifolia Sm.) (348)	R									
Melaleuca linariifolia Sm. (348)	O	O					O			
Melaleuca nodosa Soland. ex Gaertn. (347)	X	X	X	X	X	O	O			
Melaleuca styphelioides Sm. (347) (not at Rookwood Cemetery)	O	X	X	X	O		O			
xMelaleuca quinquenervia (Cav.) S.T. Blake	O				O					
Melaleuca thymifolia Sm (348)	X	O		O	O		X			
Angophora bakeri C. Hall (311)	X			O		O	X		O	
Angophora floribunda (Sm.) Sweet	R	X	R	R	R	O	X			
(Angophora costata (Gaertn.) Druce)	O	O								
Syncarpia glomulifera (Sm.) Niedenzu (310)	X	R	X	X	O					
xTristania conferta R. Br. (310)	O								O	

(Eucalypts cited as in Beadle et ~~alia~~ or R.D. Johnson and R. Marryatt, Taxonomy and Nomenclature of Eucalypts, Forest Research Inst. Leaflet 92)

	C	D	1	2	3	4	5	6	7	8
(Eucalyptus acaciiformis Deane et Maiden)	(O)	(O)								
Eucalyptus amplifolia Naudin (324)		O	R	R		O	O			
(Eucalyptus botryoides Sm.)	(O)	(O)								
(Eucalyptus cinerea F. Muell. ex Benth.	(R)	(R)								
(Eucalyptus cladocalyx F. Muell.)	(O)	(R)								
xEucalyptus ~~citreora~~ citriodo ra Hook.	X	(O)		O		O			X	O
(Eucalyptus crebra F. Muell.) (318)		(R)								
(Eucalyptus eximia Schau.) (334)	(R)									
(Eucalyptus elata Dehnh.) (327)		(R)								
Eucalyptus eugenioides Sieb. ex Spre ng. (330)	X	X	O	O	O	O	O		O	O
Eucalyptus fibrosa F. Muell. ssp. fibrosa (317)	X	X	X	X			O			
Eucalyptus globoidea Blakely (331)	X	O?	O	X		O?	O		O	
(Eucalyptus globulus Labill. ssp. globulus (-))	(R)									
xEucalyptus globulus Labill. ssp. maidenii		R								[illegible]
(Eucalyptus globulus Labill. ssp. ~~st. johnii~~)	(O)	(O)								
(Eucalyptus grandis W. Hill ex Maiden) (322)	(O)									
(Eucalyptus gummifera (Gaertn.) Hochr.) (335)	(R)									
(Eucalyptus ~~longifolia~~ leucoxylon F. Muell.)		(R)								
Eucalyptus longifolia Link. (315)	X	X	X	X					O	
(Eucalyptus maculata Hook. (315)	(X)	(O)								
(Eucalyptus melanophloia F. Muell.)		(R)								
xEucalyptus melliodora A. Cunn. ex Schau. (319)	O	O							O	
xEucalyptus microcorys F. Muell.	X	X							X	X
Eucalyptus moluccana Roxb. (337)	R	X	X	X			O			

MYRTACEAE (cont.)	C	D	1	2	3	4	5	6	7	8
(Eucalyptus nicholii Maiden et Blakely)	(O)	(O)								
?Eucalyptus paniculata Sm. (318)	O	R		O					O	
Eucalyptus paramattensis C. Hall (324) ~~var. sphaerocalyx~~	R			R					R	
(Eucalyptus piluiaris Sm.) (337)	(R)	(R)								
?Eucalyptus punctata DC. (321)	R	O	O	O					R	
Eucalyptus resinifera Sm. (333)	X	X	X	X			X			
(Eucalyptus robusta Sm.) (332)	(X)	(X)								
xEucalyptus saligna Sm. (336)	O	(O)			O				O	
Eucalyptus sclerophylla ~~A. Cunn. ex Woolls~~ (Blakely) L.Johnson & D. Blaxell A Cunn. ex Woolls	O			O						O
?Eucalyptus sideroxylon/ssp. sideroxylon	(O)	O		R						
(Eucalyptus smithii R.T. Baker) (341)	(R)									
?Eucalyptus sp. - a scribbly gum?	R									
Eucalyptus tereticornis Sm. (324)	O	R	R	R	O				O	O
(Eucalyptus viminalis Labill. (317)		(R)								
NYCTAGINACEAE										
xBougainvillea sp.	R	R			R				R	
xMirabilis jalapa L. (211)		R					R			
OCHNACEAE										
xOchna serrulata (Hochst.) Walp.	O	O	O	O						
OLEACEAE										
xLigustrum lucidum Ait. (415)	R	R	R	R						
xLigustrum sinense Lour. (415)	R	O	R	R			O			
Notelea longifolia Vent. (415)	X	X	O	X	XO					
Notelea ovata R. Br. (415)		R		R						
Onagraceae										
Epilobium cinereum A. Rich. (205)	O						O			
OXALIDACEAE										
Oxalis corniculata L. (199)	X	X	O	O	O					
xOxalis articulata Sav. (199)	R	R							R	R
xOxalis corymbosa DC. (198)	R	R								R
XOxalis latifolia H.B. et K. (199)	R	R								R
xOxalis pes-caprae L. (198)	R	R					R		R	R
xOxalis purpurea L. (198)	R								R	
PAPAVERACEAE										
xPapaver hybridum L. (158)		R					R			R
xPapaver setigerum DC (158)		R								R
PAPILIONACEAE										
Bossiaea buxifolia A. Cunn. (301)		O			O					
Bossiaea prostrata R. Br. (301)	O	O		O	O					
Chorizema parviflorum Benth. (282)	O	O		O	O					
Daviesia ~~ul~~ ulicifolia Andr. (285)	O	X	O	O	O	R				R
Desmodium varians Endl. (295)		X	X	X						
Dillwynia juniperina Lodd (294)	X	X	O	X	X	O				
xDipogon lignosus (L.) Verd.	R	R							R	R
Dillwynia parvifolia R.Br. var parvifolia (292)	X		X	X	O					
Erythrina sp.	R	R					R		R	

PAPILIONACEAE (cont.)	C	D	1	2	3	4	5	6	7	8
Glycine clandestina Wendl. (306)	OX	X	X	X	X					
Glycine tabacina Benth. (306)	O	O	O	O	O					
Gompholobium glabratum Sieb. ex DC. (284)		O			O					
Gompholobium minus Sm. (284)	R			R						
Hardenbergia violacea (Schneev.) Stearn (305)	X	X	X	X	X	O				O
Hovea longifolia R. Br. ex Ait. (300)		O					O			
Indigofera australis Willd. (304)		O	O	O	O					O
Jacksonia scoparia R.Br. (294)		R	R		R					
Kennedia rubicunda Vent. (305)	X	O		X	O	O				
xLupinus sp.	R									R
xLotus hispidus Desf. ex DC (296)	O				O					
XLotus angustissimusL. (296)	X	X		X	X					
xMedicago polymorpha L. var. vulgaris (Benth.) Shin. (299)	RX	RX			RX					RX
xMedicago sativa L. (299)	R	R			R					R
xMelilotus indica (L.) All.(298)	O	O			O					O
Mirbelia rubiifolia (Andr.) G. Don (281)	R						R			
Oxylobium ilicifolium (Andr.) Domin (283)	O			O						
Pultenaea retusa Sm. (286)	R	R			R					R
Pultenaea villosa Willd. (290)	X	X	R	O	O	X			O	O
xRobinia pseudoacacia L. (304)	X								X	
xTeline monspessulana (L.) C. Koch (302)	O	O			O	O				O
xTeline linifolia (L.) Webb et Berth	O									O
xTrifolium arvense L. (298)	R	R			R					R
xTrifolium dubium Sibth. (296)	X	X			X		X			X
xTrifolium campestre Schreb. (296)	O	O			O		O			O
xTrifolium glomeratum L. ~~[illegible]~~ (297)	X	X			X		X			X
xTrifolium pratense L. (297)	R	R			R					R
xTrifolium repens L. (297)	X	X			X		O			O
xTephrosia grandiflora (L'Her.ex Ait.) Pers. (304)	R			R			R			
xVicia angustifolia L. (304)	O	O			O		O			O
xVicia hirsuta (L.) S.F. Gray (305)	O	O			O		O			O
xVicia sativa L. (304)	O	O			O		O			O
xVicia tetrasperma (L.) Schreb. (305)	O	O			O		O			
(Wisteria sinensis)	R									
Viminaria juncea (Schrad.) Hoffmgg (294) ~~[illegible]~~	R						R			
xUlex europaeus L. (302)	O								O	
Zornia dyctiocarpa DC. (295)		R			R					
PHYTOLACCACEAE										
xPhytolacca octandra L. (187)	O	O	O	O			O			
PITTOSPORACEAE										
Billardiera scandens Sm. (2832)	R	O		O						
Bursaria spinosa Cav. (251)	X	X	O	X	O					
Pittosporum revolutum Ait. (251)	O	O	O	O						
Pittosporum undulatum Vent. (251)	O	O	O	O						

	C	D	1	2	3	4	5	6	7	8
PLANTAGINACEAE										
xPlantago coronopus L. (4 33)	R						R			
xPlantago lanceolata L. (432)	X	X			X	O	X			X
xPlantago varia R. Br. (433)		X			X					
POLYGONACEAE										
xPolygonum arenastrum	R						R			
xPolygonum aviculare L. sens lat.(184)	O	O				O				O
Polygonum decipiens R. Br. (185)	O	X					X			
Polygonum x lapathifolium L. (185)	R	R					R			
Rumex brownii Campd. (183)	O	O			O					O
xRumex crispus L. (184)	X	X			O		X			O
xRumex conglomeratus Murray (183)	O	O			O		O			O
POLYGALACEAE										
xPolygala myrtifolia L. (170)	R								R	
xPolygala virgata Thunb. (170)	O						O		O	
PORTULACACEAE										
x Portulaca oleracea L. (181)	X	R			X				X	R
PRIMULACEAE										
xAnagallis arvensis L. (430)	X	X					X			X
(Primula malacoides)		R								
PROTEACEAE										
Banksia aspleniifolia Salisb. (220)	R			R						
Banksia spinulosa Sm. (typ~~ical~~e form) (218)	X			X						
Isopogon anemonifolius (Salisb.) Knight var anemonifolius	R			R						
Persoonia laurina Pers.	R			R						
Persoonia linearis Andr.		R					R			
Hakea sericea Schrad.(221)	X	R		O		X	R			
RANUNCULACEAE										
Clematis aristata R. Br. ex DC.(154)	R	O	R	O						
Clematis glycinoides DC. (154)		O	R	O						
Ranunculus lappaceus Sm. (155)		R		R			R			
SALICACEAE										
xSalix babylonica L. (354)		O					O			
RHAMNACEAE										
Pomaderris ferruginea Sieb ex Fenzl. (366)		R		R			R			
Pomaderris lanigera (Andr.) Sims (366)		R					R			
Pomaderris prunifolia Fenzl in Hueg.	R			R						
RUBIACEAE										
Opercularia aspera Gaertn. (425)	[illegible]	R	[illegible]	R	[illegible]					
Opercularia diphylla Gaertn. (425)	O	X	O	X	O					
Opercularia varia Hook f. (425)		R					R			
Pomax umbellata (Gaertn.) Soland. ex A. Rich. (424)	X		X							
xRichardia stellaris (Cham.et Schlecht) Stand.	O	O			O					
ROSACEAE										
xCotoneaster sp.	R	R		R					R	
xPhotinia glabra		R				R	R			

ROSACEAE (cont.)	C	D	1	2	3	4	5	6	7	8
xPrunus persica		R					R			
xPrunus domestica		R					R			
xRaphiolepis indica (L.) Lindl.	R								R	
xRosa spp.	O	R					R		O	R
xRubus vulgaris Weihe et Nees (260)	O	O		R			O		O	
xSpiraea cantoniensis	R	R							R	R
(RUBIACEAE) - see previous page										
RUTACEAE										
Asterolasia correifolia Benth. (382)		R					R			
Boronia polygalifolia Sm. (376)		O	O							
Correa reflexa (Labill.) Vent. var reflexa (380)		O	O	O		R				
Zieria smithii Andr. (379)		O		R			O			
(SALICACEAE) - see previous page										
SANTALACEAE										
Exocarpos cupressiformis Labill. (373)	R	O	R	O						
Exocarpus strictus R. Br. (373)		R		R						
SAPINDACEAE										
xCardiospermum grandiflorum Swartz.(388)		X					X			
Dodonaea triquetra Wendl. (386)		X	X	X						
SOLANACEAE										
xCestrum parqui L'Her. (489)			R				R			
xCestrum aurantiacum Lindl. (489)	R	R	R				R			
xLycium ferocissimum Miers (490)		R				R				
(xPetunia hybrid)										
xSolanum mauritianum Scop. (487)		R	R				R			
Solanum nodiflorum Jacq. (488)		R					R			
xSolanum nigrum L. (488)	O	X	X	X						
xSolanum pseudocapsicum (488)		O	R	O						
xSolanum sodomaeum L. (489)		R								R
SCHROPHULARIACEAE										
xMisopates orontium (L.) Rafin.	O	O			O					
xVeronica persica Poir. (499)	O	O					O			O
(Cymbalaria muralis Baumg.)										
STERCULIACEAE										
(Brachychiton acerifolium (A. Cunn.ex G. Don) F. Muell. 239)										
Brachychiton populneum R. Br. (239)		R	R	R						
Lasiopetalum parviflorum Rudge (240)	R	X	X	R						
Rulingia pannosa R. Br. (239)	R	X	X	R						
STACKHOUSIACEAE										
Stackhousia viminea Sm. (262)	X	X		X	X					
STYLIDIACEAE										
Stylidium graminifolium Swartz ex Willd. (437)	X			X	X				X	
THYMELAEACEAE										
Pimelea linifolia Sm. (210)	R	X	O	X	X					
TROPAEOLACEAE										
xTropaeolum majus L. (202)	R	R		R						

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UMBELLIFERAE	C	D	1	2	3	4	5	6	7	8
xApium gra veolens L. (396)		R					R			
xApium leptophyllum (Pers.) F. Muell.	O	O			O		O			O
xFoeniculum vulgare Mill.	R	X				R	X			R
xHydrocotyle bonariensis Lam. (394)	R						R			
Platysace ericoides (Sieb. ex. Spreng.) C. Norman	X			X	X				X	
VALERIANACEAE										
xCentranthus ruber DC (Black IV 801)		O								O
VERBENACEAE										
xLantana camara L.	R	O	O							
xLantana montevidensis (Spreng.) Briq.	R								R	
XVerbena bonariensis L.	X	X		O	O		X			O
Verbena officinalis L.	O	O					O			
VIOLACEAE										
xViola betonicifolia Sm. (168)		O	O	R						

SUBDIVISION MONOCOTYLEDONES

AGAVACEAE	C	D	1	2	3	4	5	6	7	8
xAgave americana L.	R								R	
xPhormium cookianum		R					R			
ALISMATACEAE										
xSagittaria graminea Michx. var. weatherbiana (Fern.)Bogin (one largecolony)		X					X			
AMARYLLIDACEAE										
xAllium neapolitianum Cyr.	R								R	
xAgapanthus orientalis	R	R								R
xCrinum pedunculatum R. Br.		R					R			
xLeucojum aestivum		R					R			
xNarcissus (jonquilla?)		R	R				R			
xNothoscordum inodorum (Ait.) Nicholson (540)	X	O					X			O
xHippeastrum x equestre (Dutch Hybrid)		O					O			
CANNACEAE										
XCanna indica L.		R					R			
xCanna sp.		R					R			
ARACEAE ARACEAE										
xZantedeschia aethiopica (L.) Spreng.		R					R			

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	C	D	1	2	3	4	5	6	7	8
COMMELINACEAE										
xTradescantia albiflora Kunth. (525)	O	X		R			X			
CENTROLEPIDACEAE										
Centrolepis strigosa (R. Br.) Roem. et Schult. (591)	R						R			
CYPERACEAE										
Carex inversa R. Br. (617)		O			O					
Cyathochaeta diandra Nees (604)	X		O	O	X				X	
Cyperus brevifolius (Rottb.) Hassk. (603)		O			O		O			
xCyperus eragrostis Lam. (600)	O	O			O		O			
Cyperus mirus C.B. Clarke (601)		[illegible]					R			
Cyperus tenellus L. f. (601)	O						O			O
Lepidosperma laterale R. Br. (612)	O	X		X	O					
Lepidosperma lineare R. Br. (612)	R			R						
Gahnia aspera (R. Br.) Spreng. (614)		O		O			O			
Gahnia melanocarpa R. Br. (614)		O		O						
Ptilanthelium deustum (R. Br.) Kükenth (611)	O				O				O	
Schoenus apogon Roem. et. Schult. (610)	O						O			
xScirpus chlorostachys	R							R		
Scirpus inundatus (R.Br.) Poir.	O							O		
xScirpus prolifer Rottb. (606)	O							O		
HYPOXIDACEAE										
Hypoxis hygrometrica Labill. (552)	O	X			X					
GRAMINEAE (Poorly collected, Rookwood) (Note that arrangement is not alphabetical but as in Beadle *et alia*)										
xBromus diandrus Roth. (632)	R	R		R	R					R
xBromus molliformis L.		R					R			
xBromus rubens L.		R					R			
xCeratochloa unioloides H.B.K. (632)	O	X			O		X			O
xVulpia myuros (L.) Gmel. (633)	X	X			X					X
xVulpia bromoides (L.) S.F. Gray (633)	X	X			X					X
xPoa annual L. (634)	O	O			O		O			
xPoa affinis R. Br. (635)	R	R			R		R			
Poa sieberana Spreng. var. sieberana (636)	O	O		O	O	O				
xPoa ~~sieberana~~-pratensis L. (635)		R			R					
xDactylis glomerata L. (637)		O			O					
xBriza maxima L. (637)	O	O		O	O		O			O
xBriza minor L.	X	X		O	X		X			O
xBriza triloba Nees (637)		R			R					
xLolium multiflorum Lam (639)	X	X			O	O	O			X
xLolium perenne L.	X	X			O	O	O			X
xTriticum aestivum L. (640)		R								R
Phragmites australis (Cav.) Trin. et Steud. (641)		X					X			

GRAMINEAE (cont.)	C	D	1	2	3	4	5	6	7	8
xCortaderia selloana (Schult.) Aschers et Graebn. (641)		R					R			
Eragrostis brownii Nees ex Steud. (643)	X	X			X	X				X
xEragrostis curvula (Schrad.) Nees		R					R			
Eragrostis leptostachya Steud. (642)		O			O					
Eragrostis philippica Jedwabnick (642)		O			O					
xEleusine indica (L.) Gaertn. (644)		O			O	R				O
xEleusine tristachya (Lam.)Lam.		O			O					O
xSporobolus africanus (Poir.) Robyns et Tournay (645)	X	X				X				X
Sporobolus elongatus R. Br. (645)	O	O			O					
xChloris gayana Kunth. (646)		R			R					
Chloris truncata R. Br. (645)		X			X		X			
xChloris virgata Swartz (646)		R								R
xCynodon dactylon (L.) Pers. (646)	X	X			X	X	X			X
xAvena barbata Brot. (647)	X	X			O		X			X
xAvena fatua L.	R									R
xAvena ludoviciana Dur.	R	R								R
xAvena sterilis L. (647)	R									R
xHolcus lanatus L. (648)	R						R			
Amphibromus neesii Steud. (648)		R					R			
Danthonia longifolia R. Br. (650)		R								
Danthonia pallida R. Br. (649)	R						R			
Danthonia purpurascens J. Vickery(651)	X	X		O	O	X				O
Danthonia racemosa R. Br. (651)		R		R						
Danthonia setacea R. Br. (650)		O			O					
Agrostis aemula R. Br. (652)	X	X		O	X		X			O
Agrostis avenacea Gmel. (652)	X	X		O	X		X			O
Deyeuxia quadriseta (Labill.) Benth. (653)	X	X		O	X					
Echinopogon ovatus (Forst. f.) Beauv.	X	X	R	X						
Echinopogon caespitosus C.E. Hubbard (654)	X	X	X	X						
Dichelachne sciurea (R.Br.) Hook f. (655)	X	X	O	O	X	O	X			O
Dichelachne rara (R. Br.) J Vickery		R			R					
xPolypogon monspeliensis (L.)Desf.(655)	R	R						R		
Stipa mollis R. Br. (656)	R				R					
Stipa nervosa J. Vickery var. nervosa	X	X	R	X	X					
Stipa pubescens R. Br. (657)	X	X		X	O					
Stipa scabra Lindl.		O		O	O					
Aristida ramosa R. Br. (658)		R			R					
Aristida vagans Cav. (658)	X	X		X	X					
xPhalaris tuberosa L. (661)		O			O					O
xPhalaris minor Retz. (661)		O			O					
Microlaena stipoides (Labill.) R. Br. (661)	X	X	X	X	X		X			
xEhrharta longiflora Sm. (661)		R				R				
Arundinella nepalensis Trin. (662)	R						R			
Digitaria ciliaris (Retz.) Koel. (664)		O			O		O			
Digitaria parviflora (R. Br.) Hughes (664)		O		O						
Digitaria sanguinalis (L.) Scop. (664)		O			O					O

GRAMINEAE (cont.)	C	D	1	2	3	4	5	6	7	8
xStenotaphrum secundatum (Walt.) Kuntze (665)	O	R					O			
Eriochloa pseudoacrotricha (Stapf. ex Thell.) Black (665)	R	R			R					
xAxonopus affinis A. Chase (665)		R					R			
Brachiaria foliosa (R. Br.) Hughes (665)		R					R			
xPaspalum dilatatum Poir. (666)	X	X	R	O	X	X	X		X	X
Paspalum paspaloides (Michx.) Scribn.		O						O		
xPaspalum quadrifarium Lam. (666)		O				R	O			
xPaspalum urvillei Steud. (666)	R								R	
Paspalidium aversum J. Vickery (667)		R		R						
Entolasia marginata (R.Br.) Hughes (667)		O	O	O	R	R	O			
Entolasia stricta (R. Br.) Hughes (667)	X	X	O	X	X	X				O
Panicum simile Domin (669)	R				R					
Oplismenus imbecillis (R. Br.) Roem. et Schult. (670)		R								
xEchinochloa crus-galli (L.) Beauv. (671)		O			O					O
xSetaria glauca (L.) Beauv. (671)		R					R			
xSetaria geniculata (Lam.) Beauv. (671)	X	X	O	O	X		X			O
xSetaria palmifolia (Koen.) Stapf		R					R			
xPennisetum clandestinum Hochst. ex Chiov. (672)	X	X		R	X	O	X		O	X
xPennisetum macrourum Trin. (672)	X				X		O		X	X
Imperata cylindrica (L.) Beauv. var. major (Nees) C.E. Hubbard (674)	X	X	O	O	O	O	X			
xSorghum halepense (L.) Pers. (675)		R								
xSorghum leiocladum (Hack.) C.E. Hubbard (675)		R			R					
xBothriochloa macra (Steud.) S.T. Blake (676)		R		R	R					
Cymbopogon refractus (R. Br.) A Camus		R	R	R	R					
Themeda australis (R. Br.) Stapf	X	X	R	O	X	R	R			O

AMARYLLIDACEAE -see back several pages.

IRIDACEAE

xCrocosmia X crocosmiiflora (Hort. ex Lemoire) N.E. Br. (545)	R								R	
xIris germanica L. (541)		R								R
xIxia (capillaris?)	O				O				O	
xIxia flexuosa L. (544)	O				O				O	
xIxia (X maculata?)	O				O				O	
xGladiolus cuspidatus Jacq. (546)	O	O					O			
xFreesia refracta (Jacq.) Klatt var. odorata (Klatt) Baker (544)	O	O		O	O					
xRomulea longifolia (Salisb.) Baker (542)	X	X			X					
xSisyrinchium micranthum Cav.	O	O					O			O
xSparaxis sp.		R			R					
xWatsonia bulbifera	X	X			O		X			
xWatsonia aletroides	R								R	
xWatsonia hybrids	X			X					X	
xWatsonia (marginata?)	O			O					O	
xTritonia lineata (Salisb.)Ker-Gawl.(545)	X			X					X	O
Patersonia longifolia R. Br. (543)	X			X	X				X	

JUNCACEAE	C	D	1	2	3	4	5	6	7	8
xJuncus articulatus L. (588)		0					0	0	[illegible]	
xJuncus bufonius L. (587)		0					0	0	[illegible]	
xJuncus capitatus Weig. (587)	0							0		
Juncus continuous	0						0			
Juncus fockei Buchen (588)	R				R		R			
Juncus homalocaulis F. Muell. ex Benth (587)		R	R							
Juncus planifolius R. Br. (588)	R	R					R	R		
Juncus procerus E. Mey (589)	R	R			R					
Juncus sarophorus L.A.S. Johnson (589)	R	R			R					
Juncus sp. nov.	R				R					
Juncus subsecundus N.A. Wakefield (589)	R						R			
Juncus usitatus L.A.S. Johnson (589)	X	X			X		X			
Juncus vaginatus R. Br. (589)		R								R
LILIACEAE										
xAloe sp.	R	R				R				
Arthropodium milleflorum (DC.) Macbride (532)		0	0	0						
xAsparagus officinalis L. (531)	R	X	R	X						
xAsparagus plumosus Baker (530)		R	R							
xAsparagus sprengeri Regel (530)	R	R	R	R						
Caesia vittata R. Br. (533)	[illegible]	0			[illegible]					
Caesia parviflora (533)	0	X			X					
Dianella caerulea Sims (533)	X	X	R	0	X	R				
Dianella laevis R. Br. (534)	0			0	0					
Dianella revoluta R. Br. (534)		0		0						
xMyrsiphyllum asparagoides (L.) Willd. (531)	0	X	0	0			X			
Laxmannia gracilis R. Br. (535)	0	0		0	0					
Thysanotus tuberosus R. Br. (532)	0	0		0	0					
ORCHIDACEAE										
Diuris aurea Sm. (565)	X			X	X					
Diuris brevifolia Rogers (566)	X	0		X	X					
Diuris maculata Sm. (565)	0	0		0	0					
Diuris sulphurea R. Br. (566)	R	R		R	R					
Diuris punctata Sm. (565)	R								R	
Microtis parviflora R. Br. (567)	X			X	X					
Microtis unifolia (Forst. f.) Reichb.f.	X			X	X					
Orthoceras strictum R. Br. (566)	R			R						
Pterostylis nutans R. Br. (579)		R		R						
Thelymitra pauciflora R. Br. (564)	X	R		X	X					
PALMAE										
xPhoenix canariensis	R			R			R		R	
PHILESIACEAE										
Eustrephus latifolius R. Br. (517)	R	0	0	0						
PONTEDERIACEAE										
Eichhornia crassipes (Mart.) Solms (526)	R							R		
TYPHACEAE										
Typha orientalis Pers. (556)	R	0						0		

XANTHORRHOEACEAE	C	D	1	2	3	4	5	6	7	8
Lomandra cylindrica Lee (549)	O				O					
Lomandra filiformis (Thunb.) J. Britt. ssp. ~~[illegible]~~ coriacea Lee (549)	O	O		O	O					
Lomandra fluviatilis (R. Br.) Lee (550)		O			O					
~~[illegible]~~ Lomandra gracilis (R. Br.) Lee	X				X					
Lomandra multiflora (R. Br.) J. Britt.		O		O						
Lomandra longifolia Labill. (549)	O	O		O						
Xanthorrhoea resinosa Pers. ssp. concava Lee (547)	O	O	X	O	O		O		O	

Appendix II - List of
Species Collected only at Rookwood

S = species normally growing on soils derived from sandstones or their ecotones

PTERIDOPHYTA
OLEANDRACEAE
xNephrolepis cordifolia
GYMNOSPERMAE
ARAUCARIACEAE
xAraucaria bidwillii
(Araucaria columnaris)
PINACEAE
xPinus halepensis
xPinus pinaster
xPinus pinea
xPinus radiata

ANGIOSPERMAE
DICOTYLEDONES
APOCYNACEAE
xVinca major
CARYOPHYLLACEAE
xParonychia brasiliana
~~xSpergularia marina~~ X
XXXXXXXXXXXX
CASSYTHACEAE
Cassytha glabella
CASUARINACEAE
Casuarina littoralis
CHENOPODIACEAE
Suaeda australis
COMPOSITAE
xCoreopsis lanceolata
xGnaphalium candidissimum
xHypochoeris microcephala van albiflora
CRASSULACEAE
Crassula sieberana
CRUCIFERAE
xRapistrum rugosum
EPACRIDACEAE
Epacris purpurascens var.purpurascens
S Monotoca scoparia
EUPHORBIACEAE
S Micrantheum ericoides
GERANIACEAE
xPelargonium [illegible]
GOODENIACEAE
Goodenia heterophylla

HALORAGACEAE
Haloragis villosa
xMyriophyllum brasiliense
LABIATAE
xLavandula (vera?)
MIMOSACEAE
Acacia longissima
S Acacia myrtifolie
xAcacia podalyriifolia
xAcacia pycnantha
xAcacia saligna
S Acacia suaveolens
MYRTACEAE
S Angophore bakeri
(Callistemon ~~salignus~~ citrinus)
xEucalyptus citriodora
xEucalyptus molliodora
xEucalyptus microcorys
S Eucalyptus paniculata
Eucalyptus parramattensis
S?Eucalyptus sclerophylla
x Eucalyptus saligna
S? Eucalyptus species - a scribbly gum?
(Melaleucahypericifolia)
xMelaleuca quinquenervia
xTristania conferta
ONAGRACEAE
Epilobium xcinereum
OXALIDACEAE
xOxalis purpurea
PAPILIONACEAE
Dillwynia parvifolia var. parvifolia
Gompholobium minus
xLupinus sp.
S Mirbelia rubiifolia
Oxylobium ilicifolium
xRobinia pseudoacacia
xMolina linifolia
xTephrosia grandiflora
xUlex europaeus
Viminaria juncea
(Wisteria sinensis)
PITTOSPORACEAE
S Marianthus procumbens
PLANTAGINACEAE
xPlantago coronopus

POLYGALACEAE
xPolygala myrtifolia
xPolygala virgata
POLYGONACEAE
xPolygonum arenastrum
PROTEACEAE
S Banksia aspleniifolia
S Banksia spinulosa
S Isopogon anemonifolius var anemonifolius
Persoonia laurina
RHAMNACEAE
Pomaderris prunifolia
ROSACEAE
xRhaphiolepis indica
RUBIACEAE
Pomax umbellata
STYLIDIACEAE
Stylidium graminifolium
UMBELLIFERAE
xHydrocotyle bonariensis
S Platysace ericoides

SUBDIVISION MONOCOTYLEDONES
AMARYLLIDACEAE
xAllium neapolitianum
CENTROLEPIDACEAE
S? Centrolepis strigosa
CYPERACEAE
S Cyathochaeta diandra
Cyperus tenellus
S? Lepidosperma lineare
S Schoenus apogon
S Ptilanthelium deustum
xScirpus chlorostachys
Scirpus inundatus
xScirpus prolifer
GRAMINEAE
xAvena sterilis
xHolcus lanatus
Danthonia pallida
Stipa mollis
Arundinella nepalensis
xPaspalum urvillei
Panicum simile
xPennisetum macrourum

IRIDACEAE

xCrocosmia x crocosmiiflora

x(Ixia capillaris?)

xIxia flexuosa

x(Ixia x maculata?)

S Patersonia longifolia

xTritonia lineata

xWatsonia aletroides

xWatsonia (marginata?)

xWatsonia hybrids

JUNCACEAE

xJuncus capitatus

Juncus continuus

Juncus fockei

Juncus sp. nov.

Juncus subsecundus

LILIACEAE

S?Dianella laevis

ORCHIDACEAE

Diuris aurea

Diuris punctata

Microtis parviflora

Microtis unifolia

S?Orthoceras strictum

PALMAE

xPhoenix canariensis

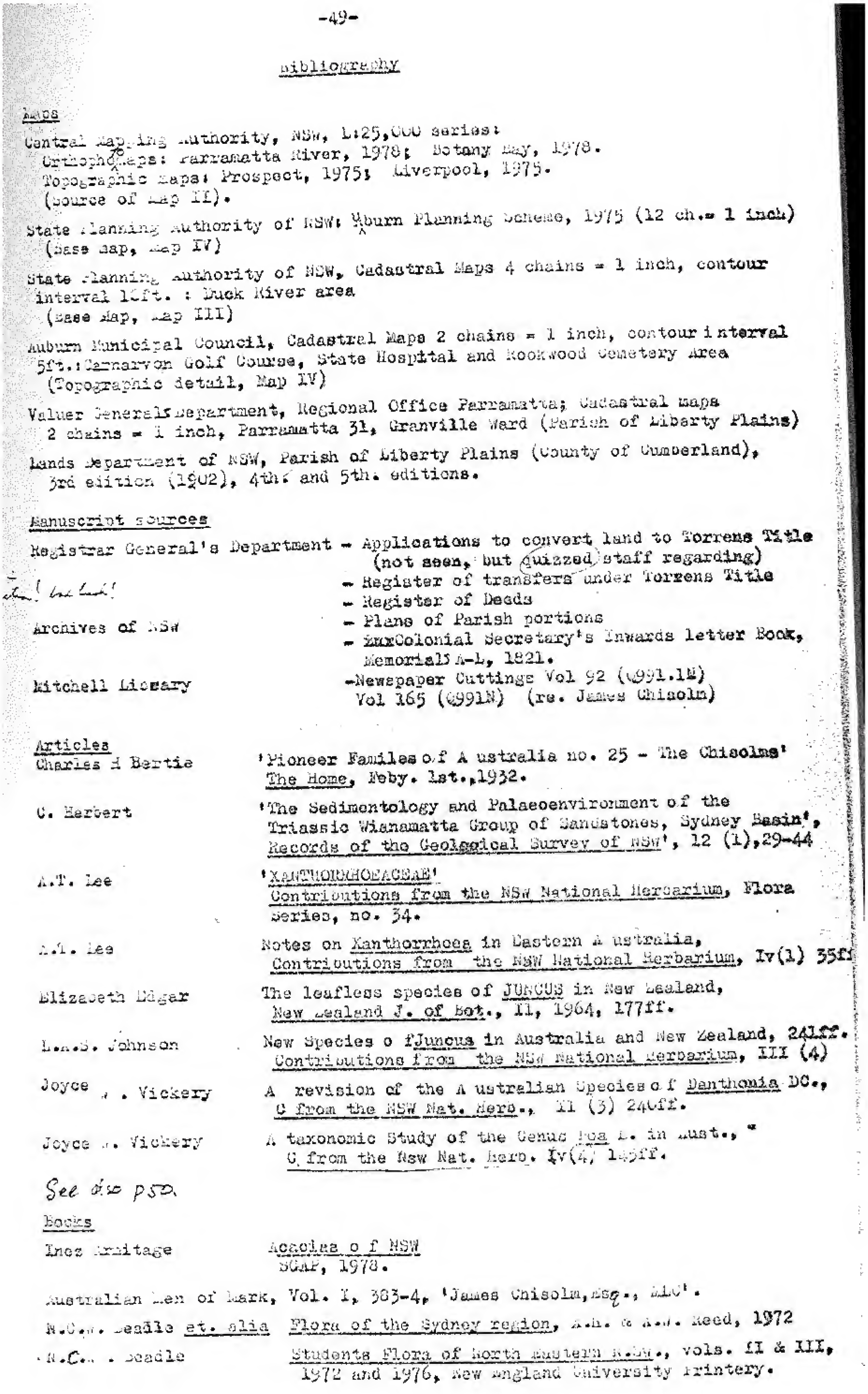
PONTEDERIACEAE

Eichhornia crassipes

XANTHORRHOEACEAE

Lomandra cylindrica

Lomandra gracilis



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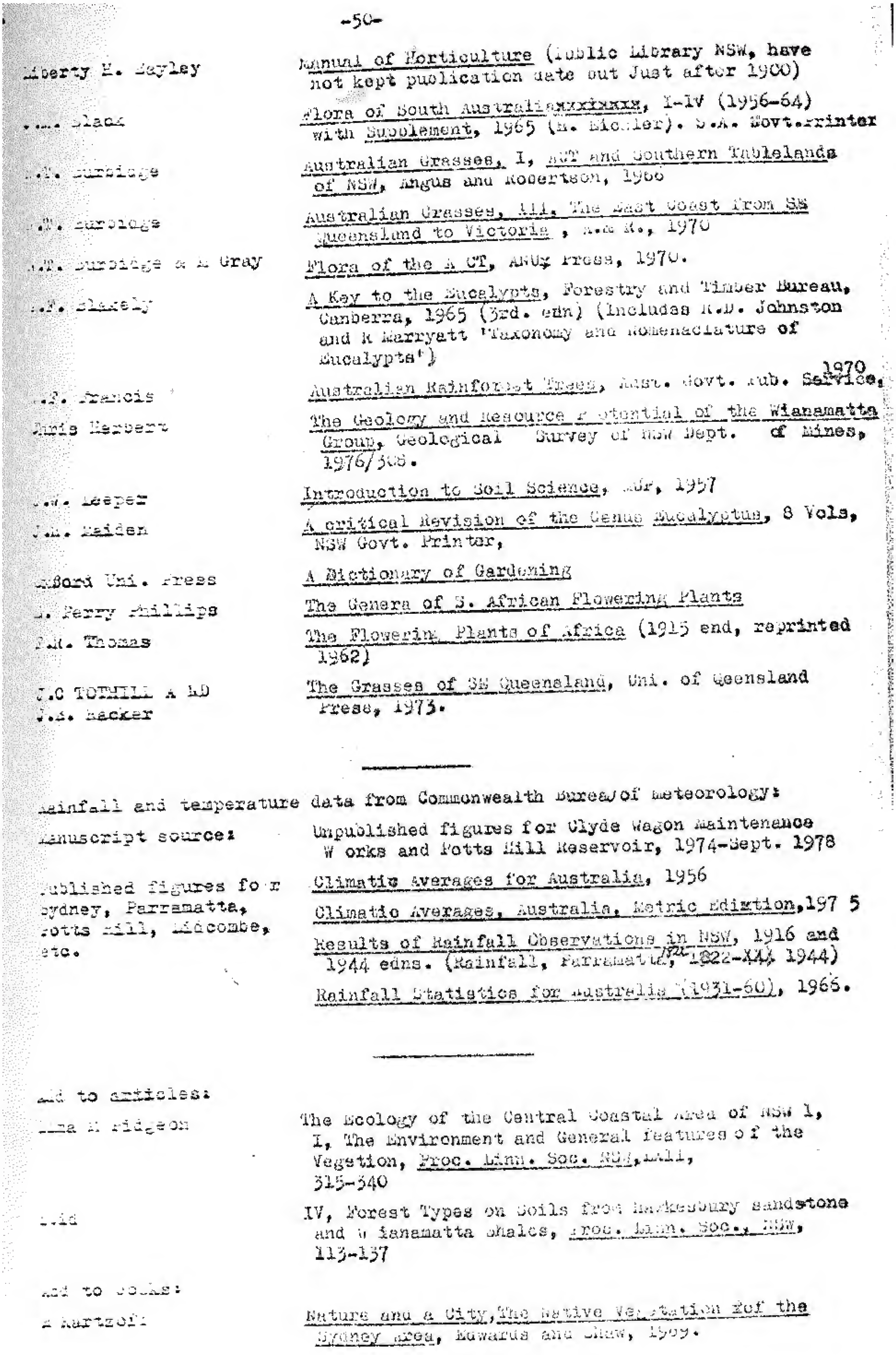

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Plant communities of the upper Murrumbidgee catchment in New South Wales and the Australian Capital Territory

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Abstract: Native vegetation of the upper Murrumbidgee catchment in southeast NSW and the Australian Capital Territory (ACT) was classified into 75 plant communities across 18 NSW Vegetation Classes within nine Structural Formations. Plant communities were derived through numerical analysis of 4,106 field survey plots including 3,787 plots from 58 existing survey datasets and 319 new plots, which were sampled in under surveyed ecosystems. All plant communities are described at a level appropriate for discrimination of threatened ecological communities and distinct vegetation mapping units.

The classification describes plant communities in the context of the upper Murrumbidgee catchment and surrounding landscapes of similar ecological character. It incorporates and, in some instances, refines identification of plant communities described in previous classifications of alpine vegetation, forest ecosystems, woodlands and grasslands across the Australian Alps and South Eastern Highlands within the upper Murrumbidgee catchment. Altitude, precipitation, soil saturation, lithology, slope, aspect and landscape position were all important factors in guiding plant community associations.

Nine Threatened Ecological Communities under Commonwealth, NSW and ACT legislation occur in the upper Murrumbidgee catchment. This study has also identified five additional plant communities which are highly restricted in distribution and may require active management or protection to ensure their survival.

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Introduction

The classification of vegetation into distinct recurring species assemblages is an essential precursor to the mapping of vegetation distribution patterns. Together, vegetation classification and mapping are commonly used to inform biodiversity impact assessment and local and regional land use planning. Systematic vegetation classification and mapping also provide valuable information to identify threats and risks to various components of biodiversity, and to prioritise specific ecological values for targeted protection.

Systematic vegetation classification based on numerical analysis of field survey data is widely used in Australia and other parts of the world where sufficient field data are available. Numerical analysis of field 'relevé' data has been progressively developed in Europe through the European Vegetation Survey project (e.g. see Bruelheide & Chytrý 2000; Tichý 2002; Schaminée *et al.* 2007; De Cáceres *et*

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al. 2009). In the development of the United States National Vegetation Classification System, Grossman *et al.* (1998) noted that vegetation classification ideally should be based on the analysis of high quality field data spanning the full geographic and environmental range of related vegetation, and the subsequent US National Vegetation Classification Standard Version 2.0 (FGDC 2008) proposed that natural vegetation types be derived from analysis of field plot data, with these data providing the fundamental information for the numerical description of types.

Within NSW, many natural resource management decisions are made by Catchment Management Authorities (CMAs) based on information and assessment at the scale of broad catchments. Within the Murrumbidgee CMA area and the ACT, the upper Murrumbidgee River catchment contains a diverse range of landscapes and vegetation types which are subject to ongoing land-use pressures including clearing of native vegetation for farming and urban development, urban expansion and ongoing pastoral management. The upper Murrumbidgee catchment has a relatively high density of existing vegetation survey plot data collected by previous vegetation studies, ranging from specific conservation reserve surveys to a large regional inventory of forest ecosystems on public lands, but to date it has not had a systematic classification of all plant communities across all Structural Formations across all tenures.

This study aimed to classify and describe the native plant communities of the upper Murrumbidgee catchment at a consistent classification scale or level of detail, based on numerical analysis of the best available set of full-floristic field survey plot data. Plant communities were delineated and described at an ‘association’ level compatible with adjacent regional vegetation classifications and with NSW Scientific Committee determinations, and a level that could be recognised in the field by people with botanical training. The study will contribute to the NSW Vegetation Classification and Assessment project (Benson 2006) and the State-wide Vegetation Information System Classification Database (OEH unpublished a).

Study Area

The study area (referred to here as the ‘upper Murrumbidgee catchment’), an area of 1.741 million ha, within the Murrumbidgee catchment in NSW and the Australian Capital Territory (ACT) (Figure 1). The upper Murrumbidgee catchment is characterised by two distinctive bioregions (or IBRAs): the Australian Alps and the South Eastern Highlands (Thackway & Cresswell 1995, IBRA version 6.1). Approximately 86% of the upper Murrumbidgee catchment falls within the South Eastern Highlands bioregion, with the Australian Alps bioregion comprising the remaining 14%. Most bioregions contain multiple subregions, based on finer differences in biophysical attributes such as vegetation,

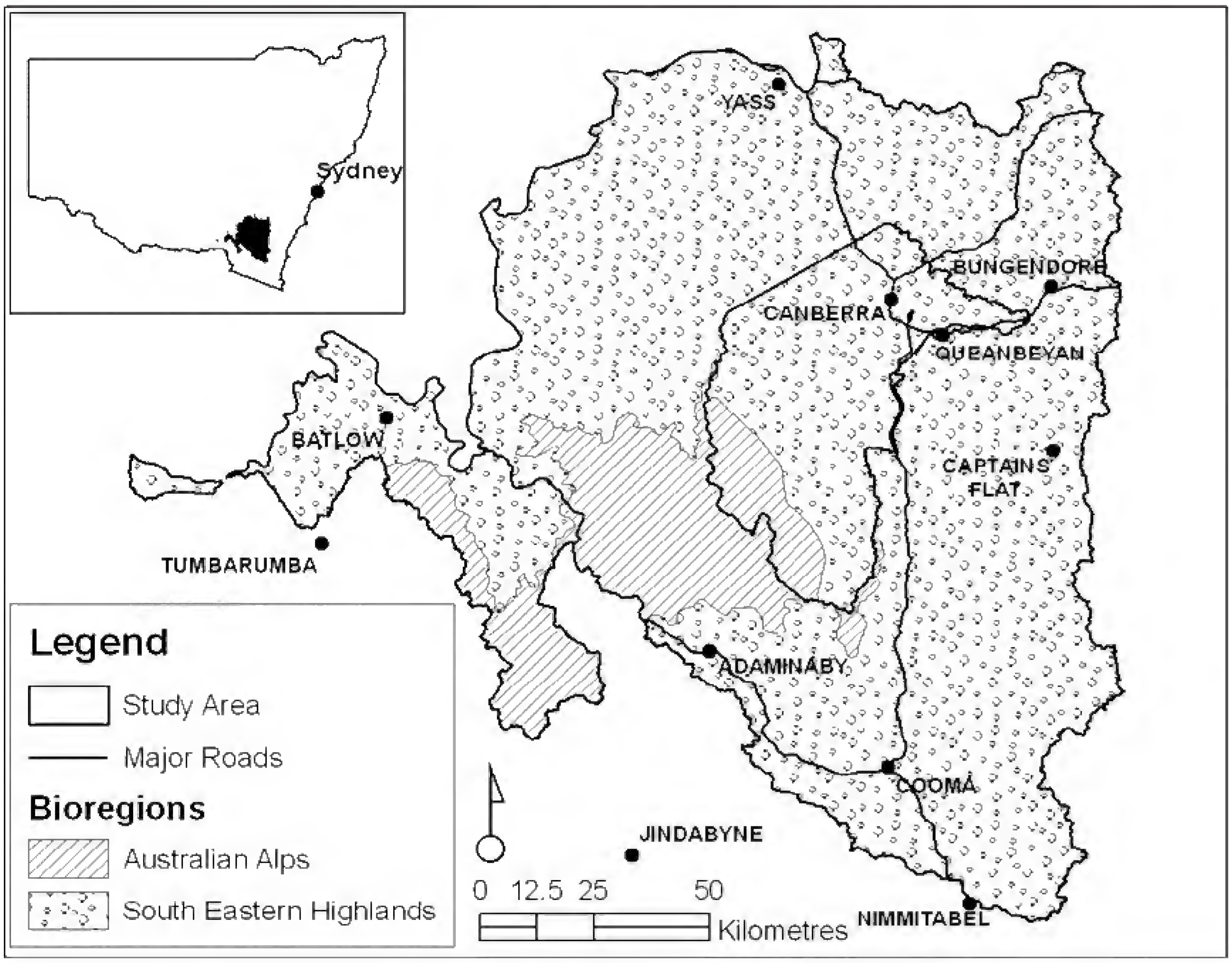

Fig. 1. The upper Murrumbidgee catchment study area including major population centres, roads and bioregions.

geology and soil type (NPWS 2003a). The Australian Alps bioregion contains only one subregion (Australian Alps), which occurs across the Alps in NSW, Victoria and the ACT. The South Eastern Highlands bioregion contains ten subregions, five of which (Bondo, Crookwell, Kybean – Gourock, Monaro and Murrumbateman) occur within the upper Murrumbidgee catchment (Figure 2). The biophysical characters of these subregions are outlined in Table 2.

The upper Murrumbidgee catchment encompasses parts of 11 local government areas: Cooma-Monaro, Goulburn-Mulwaree, Greater Hume, Gundagai, Palerang, Queanbeyan City, Snowy River, Tumbarumba, Tumut, Upper Lachlan and Yass Valley, as well as the entire jurisdiction of the ACT. Cities within the study area include Canberra and Queanbeyan, with regional centres including Adaminaby, Batlow, Bungendore, Captains Flat, Cooma and Yass. The upper Murrumbidgee catchment is primarily within the Southern Tablelands botanical subdivision, with parts of the north-west within the South Western Slopes botanical subdivision (Anderson 1961).

In developing a plant community classification for the upper Murrumbidgee catchment it was recognised that many plant communities would be distributed beyond the edges of the catchment, particularly in similar tableland environments to

Table 1: Climate data for the study area.

Location	**Altitude (m)**	**Highest mean max. mean daily temp (°C)**	**Lowest mean max. mean daily temp (°C)**	**Frost days (ave. no. days/ year of daily min. ≤ 0°C)**	**Ave. annual precipitation (mm)**	**Lowest mean monthly rainfall (mm)**	**Highest mean monthly rainfall (mm)**
Cabramurra	1482	21.4 (Jan)	- 0.9 (Jul)	81	1155	43 (Jan)	135 (Aug)
Canberra Airport	578	28.0 (Jan)	- 0.1 (Jul)	60	616	40 (Jun)	64 (Nov)
Cooma (Visitors centre)	778	27.2 (Jan)	- 2.8 (Jul)	104	533	27 (Aug)	66 (Nov)
Thredbo AWS *	1957	16.3 (Feb)	- 5.3 (Jul)	167	1355	85 (June)	151 (Sep)
Tumbarumba PO	655	28.7 (Jan)	- 0.2 (Jul)	60	976.4	54 (Feb)	107 (Aug)
Yass	520	29.5 (Jan)	1.1 (Jul)	46	651	46 (Feb)	65 (Oct)

Source: BoM (2011)

* Thredbo is located outside the upper Murrumbidgee catchment, but is included as an indication of the climate of alpine areas within the study area.

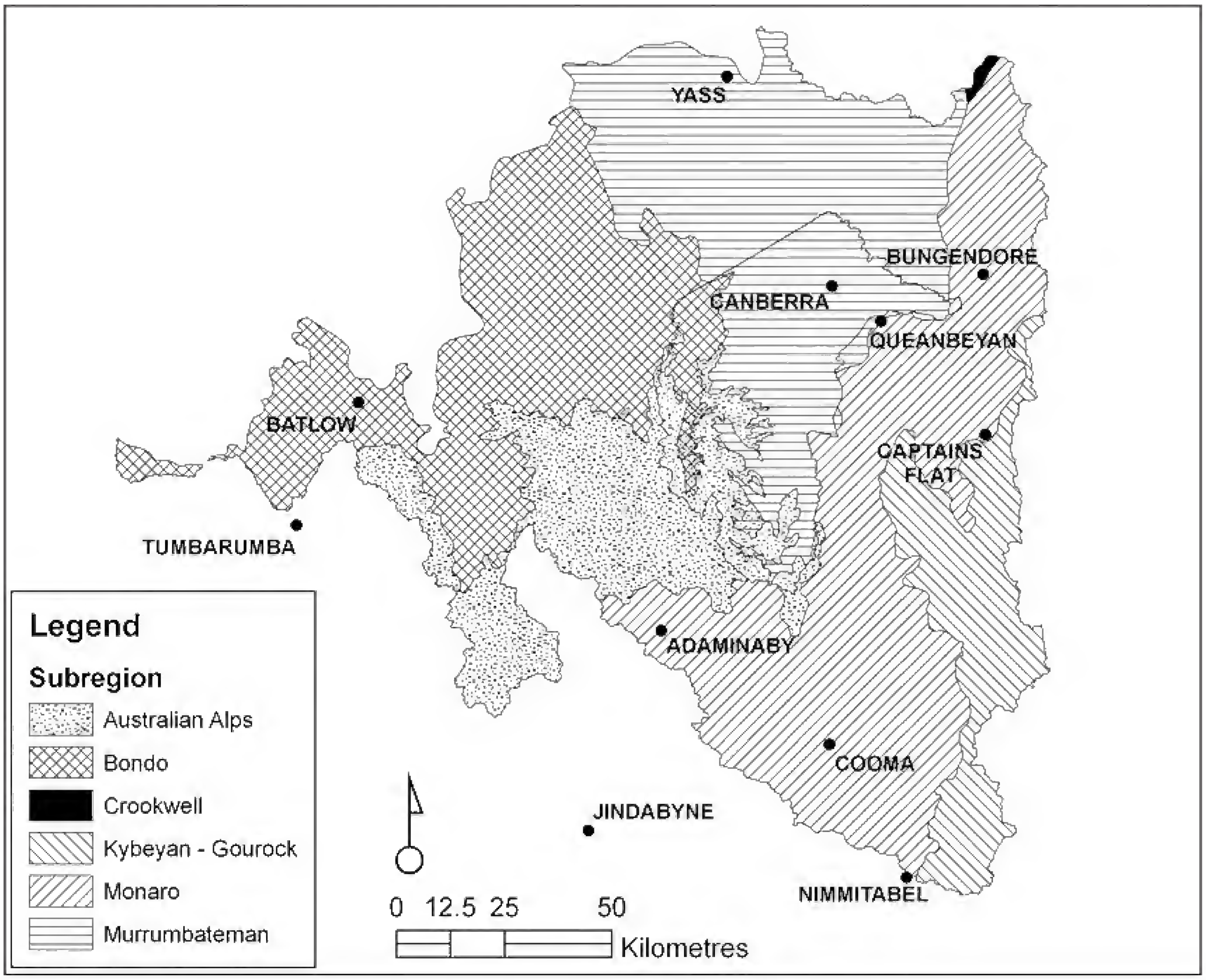

Fig. 2. IBRA subregions of the upper Murrumbidgee catchment study area.

the north and south. In order to address this issue, floristic plot data from a broader area (referred to as the 'broader analysis area') were included. This encompassed the Australian Alps and South Eastern Highlands bioregions from the Victorian border north to Oberon Shire. The broader analysis area included a 10 km buffer on the western edge of the study area, and all of Boorowa Shire.

Climate

Climate varies greatly across the upper Murrumbidgee catchment, in response to topographic variation and its effect on atmospheric pressure, wind, precipitation, light and cloud cover. The Australian Alps bioregion contains areas of alpine, sub-alpine and montane landforms, with the South East Highlands being primarily tablelands with occasional montane features (Costin 1954).

Mean annual precipitation from weather station records ranges from 533 mm at Cooma within the Monaro rain shadow to 1,115 mm at Cabramurra on the main Kosciuszko range (Table 1; BoM 2011). Annual precipitation is highest in the southwest, where alpine peaks are modelled as receiving up to 2,150 mm, much of this as snow in cooler months. Within the Monaro rain shadow, annual precipitation is modelled to be as low as 450 mm southwest of Cooma, where a lack of rainfall combined with severe winter frosts restricts tree growth (Figure 3) (Anon 2009). Cooma has the highest recorded temperature variation, with a highest mean daily temperature of 27.2°C in January and a minimum mean daily temperature of - 2.8°C in July (BoM 2011).

Settlement and landuse

The upper Murrumbidgee catchment was occupied by Aboriginal people for at least 21,000 years before European settlement (Lennon 2003, Hancock 1972). The Walgulu and Djilamatang people generally utilised the alpine areas, with Ngunnawal and Ngarigo people on the slopes and tablelands. At times, Wiradjuri people may have extended eastward into western sections of the study area (Tindale 1974). European settlers started arriving in the mid-1820s, with squatters establishing pastoral camps over much of the Monaro by the 1830s (Hancock 1972). Pastoralism commenced in the Australian Alps in the 1820s (HO & DUAP 1996) and by the 1850s most of the Alps were used for stock grazing during the warmer months (Lennon 1999).

Climate, remoteness and the rugged terrain influenced both Aboriginal and European settlement and land use patterns (Lennon 2003). Easily accessible parts of the upper Murrumbidgee catchment have been developed primarily for wool and beef production; other land uses include urban development, forestry, cereal cropping (Hancock 1972), and conservation in national parks such as Kosciuszko NP. Other land uses include gold mining, the Snowy Mountains Hydro-

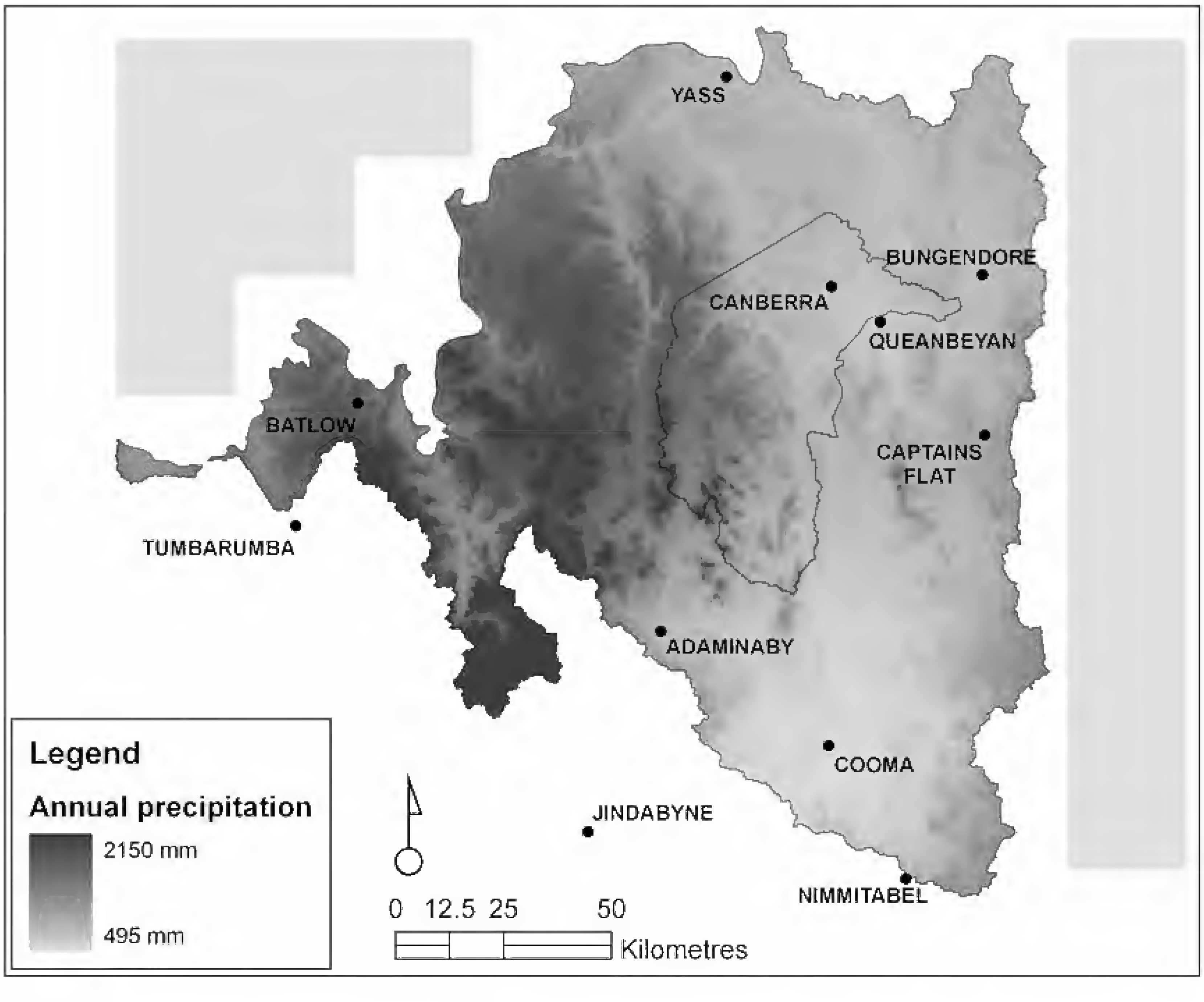

Fig. 3. Annual precipitation of the study area, showing higher rainfall in alpine and montane areas, and the dry Monaro rainshadow around Cooma.

Table 2: Characteristics of IBRA subregions of the study area.

Subregion	Area (ha)	Geology	Characteristic Landforms	Typical Soils	Vegetation
Australian Alps	200,947 (NSW) 40,378 (ACT)	Block faulted granites and Palaezoic metamorphic rocks. Small areas of Tertiary basalt with buried river gravels and lake sediments. Quaternary glacial landforms and sediments above 1,800 m, more extensive periglacial features above 2,100 m.	Low-relief high plains with steep margins and slopes and fault aligned river valleys with deep gorges and waterfalls. Relic cirque glaciers, blockstreams and periglacial solifluction lobes in highest regions.	Soils change with altitude. At lower levels in forests texture contrast soils are the norm. In the sub-alpine forests areas deep gradational soils with moderate amounts if organic matter are common. Above the treeline, wet alpine humus soils with abundant organic matter are widespread. Steep slopes have stonier, shallow profiles.	Vegetation changes with altitude, aspect, cold air drainage and soil saturation. Low elevations with dry aspects carry *Eucalyptus macrorhyncha*, *E. rossii*, *E. dives*, *E. rubida* and *E. mannifera*. Moist sites have *E. delegatensis*, *E. dalrympleana*, *E. viminalis*, *E. radiata* subsp. *radiata*, and *E. fastigata.* Between 1,000 and 1,500 m *E. delegatensis* and *E. dalrympleana* dominate and abruptly change to subalpine *E. pauciflora* subsp. *pauciflora* and *E. pauciflora* subsp. *niphophila* woodlands, heaths, grasslands and bogs between 1,500 and 1,800 m. Alpine herbfields and rare feldmark communities are found above the treeline.
Bondo	363,210 (NSW) 20,224 (ACT)	Silurian and Devonian acid intrusive, fine grained Palaeozoic sedimentary and metasedimentary rocks and areas of granite.	Rugged hills, with small plateau areas. Steep stony slopes and string structural control on ridge lines.	Red earths and red texture contrast soils. Typically thin and stony on slopes, thickening on footslopes, and becoming yellow and harsh on valley floors.	*E. radiata* subsp. *robertsonnii*, *E. macrorhyncha*, *E. viminalis* and *E. dalrympleana* open forests.
Crookwell	2,488 (NSW)	Fine grained Ordovician and Silurian sedimentary rocks, with some granites. Tertiary basalts with buried river gravels along ridges well above present streams.	Hilly, with some rugged areas and steep valleys. Hill tops may be small plateaus or capped by basalt and showing inverted relief.	Red and yellow texture contrast soils, thin and stony on steep slopes. Stony brown structured loams on basalts.	*E. bridgesiana*, *E. dalrympleana* with *E. blakelyi* and *E. melliodora*. *E. macrorhyncha*, *E. albens*, *E. dives* and *E. mannifera* on stony ridges in the north. Small patches of *E. cinerea*.
Kybeyan – Gourock	155,107 (NSW)	Devonian quartz-rich sedimentary rocks with minor areas of limestone, and areas of Silurian-Devonian granitoids at higher elevations in the south. Ordovician quartz-rich sedimentary and metamorphic rocks in the west.	Rocky ranges, moderate to steep lower to mid slopes. Stony outcrops along ridgelines.	Red and yellow texture contrast soils, becoming deeper and more poorly drained down slope. Thin brown stony loams and transitional alpine humus derived from granitoids at higher elevations in the south.	*E. fastigata*, *E. viminalis*, and *E. radiata* subsp. *radiata* on hillslopes, with *E. melliodora, E. blakelyi* and *E. mannifera* at lower elevations. Some west facing patches of *Allocasuarina nana* heathland. Strong aspect influences on plant associations.
Monaro	530,798 (NSW) 882 (ACT)	Block faulted ranges and closed lake basins in Silurian and Devonian acid fine grained sedimentary and metamorphic rocks with some granites. Extensive areas of thin Tertiary basalt flows over lake and river sediments.	Sloping plateau rising from 600 to 1 300 m north to south. Structural ridges of more resistant rock. Stepped plains on basalt with intervening low areas of granite or sedimatary rocks. Numerous shallow lakes and swamps, a few permanent. Many and closed basins and periodically dry. Area is in rainshadow with rainfall 450 – 750 mm.	Harsh yellow texture contrast soils in general. Shallow red brown to black stony loams on basalt.	*E. pauciflora* subsp. *pauciflora*, *E. viminalis*, *E. rubida*, *E. dives* and *E. dalrympleana* woodlands with *Themeda australis* understorey. *E. rossii* and *E. mannifera* on hills. Extensive grasslands of *Poa* spp., *Austrostipa* spp. and *Rytidosperma* spp. on the driest plains with clumps of *Poa* spp. amongst rocky outcrops.
Murrumb-ateman	280,798 (NSW) 174,316 (ACT)	Fine-grained Palaezoic sedimentary and metasedimentary rocks, with minor areas of course acid volcanics. Tertiary alluvial terraces along main streams.	Undulating plateau with rounded hills and peaks, entrenched meandering streams with chain of pond tributaries.	Mottled yellow and brown texture contrast soils with strongly bleashed topsoils. Dark organic loams and clay loams on valley floors. Saline patches present.	*E. blakelyi* and *E. melliodora* on lower slopes. *E. macrorhyncha*, *E. rossii* and *E. nortonii* on ridges. Areas of *E. bridgesiana* and *E. mannifera*. Limited swampy flats and valley floor grasslands.

Electric scheme and recreational ski-field development in the Alps, and orcharding in the central and western parts of the South Eastern Highlands.

Natural vegetation in the upper Murrumbidgee catchment has been affected by domestic grazing, tree clearing (including ringbarking and logging), cultivation, altered hydrology and altered fire regimes. Introduced herbivores and omnivores, including rabbit (*Oryctolagus cuniculus*), hare (*Lepus* spp.), horse (*Equus caballus*), deer (numerous genera of the *Cervidae* family), pig (*Sus scrofa*) and goat (*Capra hircus*) continue to have negative impacts on the structure and floristic composition of native plant communities. The severity of impacts varies depending on ecosystem resilience and the timing and intensity of the threats (Costin 1954).

Previous botanical studies

Past qualitative and quantitative botanical studies in the upper Murrumbidgee catchment include:

- A study of the vegetation and soils of the Monaro region and much of the Australian Alps bioregion (Costin 1954).
- Classifications of wetlands and grasslands of the Monaro (Benson & Jacobs 1994, Benson 1994).
- The Southern CRA Forest Ecosystem classification and mapping project, focussing on forest ecosystems on public lands (Thomas *et al.* 2000).
- Refinement of Thomas *et al.* (2000) undertaken by Gellie (2005).
- A classification of vegetation of the treeless alps in NSW and Victoria (McDougall & Walsh 2007).
- A classification of native vegetation of southeast NSW (Tozer *et al.* 2010), which refined and integrated previous work by Tindall *et al.* (2004), Keith & Bedward (1999) and others.
- A number of regional vegetation studies in the ACT (e.g. Ingwersen *et al.* 1974, Ingwersen 2001, Johnston *et al.* 2008, Sharp *et al.* 2007).

For a list of botanical survey data used as part of this study refer to Table 3.

Methods

Existing floristic survey data

Existing floristic survey data from the broader analysis area were compiled from datasets held by the NSW Office of Environment and Heritage in the 'YETI' database (Bedward *et al.* 2011). Datasets were assessed for inclusion in the analysis based on the following criteria (adapted from Keith & Bedward 1999):

i complete list of vascular plant species within each survey plot (i.e. full-floristic plot survey), as well as the moss *Sphagnum* spp., which was important for alpine classification;

ii plot location recorded with a precision of 100 m or better;

iii species importance values recorded on a scale that could be transformed to a common cover-abundance scale;

iv area of each plot within the range 0.04 to 0.1 ha.

Exceptions made to criterion (iv) were the dataset of McDougall & Walsh (2007), which included samples of between 0.002 and 0.05 ha, and the data of Benson & Jacobs (1994), which involved whole-lake samples of up to 215 ha in area. These datasets represented the only survey data available for these habitats within the area. The smaller area plots collected by McDougall & Walsh (2007) were considered to capture floristic variation for alpine plant communities.

The data compilation process included correction or masking of obvious taxonomic data entry errors, exclusion of plots that were clearly not full-floristic (e.g. canopy only or API-checking plots) and correction of obvious plot location errors (where georeference data did not match text location description).

A total of 3,787 survey plots from 58 survey datasets (Table 3) across the broader analysis area were accepted for inclusion in the analysis, including data from 193 plots in three surveys which were located and entered into the YETI database as part of this study. Spatial and floristic variation within these datasets formed the basis for planning additional survey using stratified and preferential sampling techniques (Bell 2013).

All plots stored in the YETI database are identified by unique alpha-numeric labels and many of the plots extracted from the current broader analysis area had been classified during one or more previous studies. The group definitions (or plot memberships of groups) of previous studies by Benson & Jacobs (1994), Gellie (2005), McDougall & Walsh (2007) and Tozer *et al.* (2010) were obtained to allow exploration of relationships between groups defined by these previous classifications and the current study.

Additional survey

Using a Geographic Information System (GIS), the distribution of existing survey plots was stratified by the NSW Landscapes ("meso-scale ecosystems") as delineated by Mitchell (2003), and revised by EcoLogical (2008). These Landscapes represent areas of similar geology, topography and climate. Based on existing survey plot data, under-sampled Landscapes were identified for further sampling. Calculations included a 10 km buffer beyond the upper Murrumbidgee catchment boundary, as existing survey plots outside this area, but within areas of similar biogeographic character would be included in the classification across the broader analysis area.

A total of 270 new field survey plots were proposed for sampling in remnant vegetation within 29 NSW Landscapes. Targeted plot locations were allocated across under-sampled Landscapes in the upper Murrumbidgee catchment using

Table 3: Datasets used as part of the floristic analysis.

YETI Survey identifier	No. of plots used	Reference
ACT_GUD	188	Ingwersen (2001)
ACT_MT.WD	106	Gilmour *et al.* (1987)
ACT_UC	107	Helman *et al.* (1988)
ALP_ASH	61	DECCW (2010a)
AUSALPS	359	McDougall & Walsh (2007)
BALLNDCARE	29	Crawford (1999)
CS_CLYDE	22	Helman (1983)
EA_TSR	83	Hibberd & Taws (1993)
EDENVI	9	Keith & Bedward (1999)
FLOYDRF	3	Floyd (1990)
kosc_xtra	19	Miles & Robertson (2008)
KOWMUNG	110	Steenbeeke (1990)
KOWMUNGHAK	5	Steenbeeke (1996)
KTWETQUD	4	Turner (2007)
MER_SR	6	DECCW (2010b)
MILES_06	16	Miles (2006)
MONWET	65	Benson & Jacobs (1994)
NADGIG_NR	12	Miles (2010a)
NALBAUGH	62	Binns & Kavanagh (1990)
NP_BONDI	24	Fanning & Rice (1989)
NP_BRIN	130	Doherty (1997a)
NP_BUR	33	Doherty (1998; 2004)
NP_DEUA	20	Gilmour (1985)
NP_ECRA	66	Keith & Bedward (1999)
NP_GOULB	36	Miles (2010b)
NP_KOSI	39	AALC (no date)
NP_MONGA	11	Miles (2007)
NP_MUND	17	Doherty (1996)
NP_SCQBYN	10	NPWS (undated a)
NP_SCRA	788	Thomas *et al.* (2000)
NP_TIND	1*	Doherty (1997b)
NP_WADAN	5	Mackenzie *et al.* (1998)
NP_WOGWO	12	Fanning & Fatchen (1990)
NPA_ABER	32	Togher (1996)
P_MONARFB4	33	Crawford (2002a)
P5MA	506	Tindall *et al.* (2004)
P5MA_XTRAS	2	Tindall *et al.* (2004)
RH	43	NPWS (undated b)
SCRA_NTH	39	Thomas *et al.* (2000)
SEFCOMB	100	Keith & Bedward (1999)
SF_BAGO	26	Binns (1997)
SF_BM	4	Binns (1997)
SF_BMFLS	64	Binns (1997)
SF_MAR	5	Binns (1997)
SF_QFS	100	Jurskis *et al.* (1995)
SFTUMB04	24	Binns (2004)
SWS_Gellie	133	EcoGIS (2004)
TARAL	15	Fisher & Ryan (1994a)
TOL_BUN_BN	35	Miles (2005a)
UMC_ACT	31	ACT CP&R (2010)
UMC_GA	54	this study
UMC1	40	this study
UMC2	26	this study
UMC3	46	this study
UMC4	29	this study
UMC5	25	this study
UMC6	32	this study
UMC7	36	this study
V_BOMBFB4	19	Miles (2005b)
V_BONDIFB4	10	Crawford (2002b)
V_COOLAFB4	9	Miles (2002)
V_COOLUFB4	9	Crawford (2002c)
V_COOMAFB4	27	Miles & McPherson (2004)
V_MONGAFB4	6	Gellie (2002)
V_TANTYFB3	13	Miles (2001)
V_TBLD_FB4	5	Miles (2004)
WARRAGAMBA	70	NPWS (2003b)
TOTAL:	4106	

* Note: 49 of the 50 survey plots collected by Doherty (1997b) were stored within the NP_SCRA survey.

a random point generator in the GIS, constrained to areas of public tenure [including national parks, State forests, travelling stock reserves (TSRs) and Crown reserves] and 22 private properties whose owners had granted access for surveys. A small number of random target locations were modified by moving to areas of greater accessibility, such as to within a few hundred metres of an access track. All moved target plots remained within the same Landscape and in a similar landscape position to that of the original randomly selected location (e.g. drainage line, mid-slope or hill top). A further 49 new field survey plots were sampled in vegetation or habitat types believed to be under-sampled based on consultation with local botanists and review of previous descriptions of plant communities across the study area.

Data collected for this study largely conform with the NSW Native Vegetation Type Standard (Sivertsen 2009), including recording of precise plot location, basic floristic structure, condition, tree health, physiography, land use, disturbance and full-floristic plot data with percent foliage cover. All surveyors estimated percent foliage cover for all taxa in each full-floristic quadrat; one team also recorded separate abundance scores. These new plots brought the total number of field survey plots available for analysis to 4,106. Table 3 summarises the sources of the plot data.

Data analysis

Floristic data from 4,106 field survey plots were collated in a relational database (Bedward *et al.* 2011) and exported in a format suitable for analysis. Through the export process all exotic taxa were excluded, a standardisation of taxonomic names was applied, and species-importance scoring systems were transformed to their closest equivalent on a cover-abundance scale of 1 to 6 (1: uncommon and less than 5% cover; 2: common and up to 5% cover; 3: up to 20% cover; 4: up to 50% cover; 5: up to 75% cover; and 6: over 75% cover) modified from Braun-Blanquet (1932). Exported data consisted of transformed cover-abundance values in a matrix of 4,106 plots (objects) by 2,067 taxa (attributes).

Exported data were examined using the homogeneity analysis algorithm developed by Bedward *et al.* (1992), to assess the number of floristic groups (i.e. the classification level) likely to be most efficient at describing the floristic diversity of the broader analysis area. This assessment, combined with review of previous plant community classifications covering parts of the study area, suggested an initial classification level of 200 groups.

Survey plot data were then analysed to search for groups of consistently co-occurring plant taxa at the chosen classification level, using the PATN software developed by Belbin (1995a, 1995b). Cluster analysis began with the PATN non-hierarchical clustering strategy 'ALOC', as recommended by Belbin (1995a) for datasets containing large numbers of objects (plots). ALOC was run with object-centroid distances calculated using the Bray and Curtis association measure, using the first plot as an initial seed, specifying an output of 200 initial groups and accepting the PATN default maximum number of iterations of *allocation -> centroid re-definition -> re-allocation* .

As outlined above, the classification dataset came from a variety of sources, and the data were known to contain survey-related variance factors with the potential to interfere with the clustering algorithm's recognition of 'real' floristic groups. These included varied plot sizes; some surveys with many records of coarse identification to genus level only (e.g. *Rytidosperma* spp.); different original species cover and abundance scoring systems used by some surveys; and irreconcilable taxonomic changes between old and recent surveys. For these and other reasons, the initial clustering output was considered likely to reflect both real (i.e. species' response to environmental gradients) and apparent (i.e. artefacts of survey method, disturbance etc.) patterns in species composition, and so the output of the automated free-ALOC clustering process was examined in detail.

The compositional attributes of each of the initial free-ALOC groups were examined by tabulating species frequencies and median cover scores using the FIDEL software developed by Bedward (1999). The homogeneity of each group was examined by computing a matrix of plot/centroid associations, and plotting in a GIS the spatial distribution of group members against mapped substrate, physiography and climate attributes. Graphical representations of group structure (dendrograms and ordinations of subset data) were also examined in PRIMER v5 (Clarke & Gorley 2001). Relationships between free-ALOC groups and the groups identified by previous numerical classifications overlapping the study area (Benson & Jacobs 1994; Gellie 2005; McDougall & Walsh 2007; and Tozer *et al.* 2010) were also examined.

Individual plots with a weak association with the nearest centroid or anomalous spatial distribution were either reallocated to a 'near-neighbour' group supported by the above information, or excluded from further analysis if they could not be reliably assigned to any other floristic group and were not considered to represent a distinct new group. At a broader level, each of the initial groups were either retained (in some cases with minor reallocation into or out of the group), split into two or more separate groups, or merged with other groups. Groups were retained where a clear compositional dichotomy was associated with an environmental gradient. Merging was considered for groups that were:

- dominated by plots from single surveys or observers, with some consistent characteristic of that survey likely to blur true composition differences (e.g. distinctive cover-score systems, high frequency of genus-only records);
- seeded by disturbed plots, such as recently burnt or logged plots dominated by dense tree regrowth, or grazed TSR plots dominated by exotic pasture with very low native species richness and cover;
- seeded by or dominated by aberrant plots, which had been missed in the first series of data cleaning. This was commonly caused by either unusually large survey plots (most plots were 20 x 20 m; larger 20 x 50 m plots have a higher likelihood of containing more than one plant community or higher species richness), plots that contained suspiciously large species lists and may have been random meanders rather than plot-bounded surveys, and plots clearly representing sampling across an ecotone (such as boundaries between wetland perimeters and forest).

The eastern edge of the broader analysis area included a small number of plots representing the margins of moist coastal/escarpment plant community types, which had been classified as such by Tozer *et al.* (2010) in their coast/escarpment/eastern tablelands context. In the absence of their related plots outside the broader analysis area, the ALOC process tended to group these plots with moist tableland plots and blur the recognition of tableland groups. This was treated by accepting the Tozer *et al.* (2010) allocations of these moist coastal/escarpment plots, and excluding these groups when considering alternative allocations of tableland plots. This is further discussed below in *Relationship with previous classifications.*

A systematic examination of all initial free-ALOC groups and group assignments produced a revised allocation of all plots to groups (or identified plots for exclusion). This revised group definition was used to seed a subsequent round of ALOC clustering, involving both a zero-iteration run (to examine the affinity of objects/plots to the revised groups) and a 10-iteration/0.8-radius run to test the stability of those groups and search for additional groups recognisable in the absence of outlier plots. The outputs of each iteration were again examined through ALOC tabulations of plot/centroid associations, group species frequency, cover and fidelity data (for non-grassland plots), comparison with previous study plot allocations, spatial distribution of plots, dendrograms etc., in order to further refine the definition of groups and the allocation of plots to those groups. This iterative process of refinement, re-run and checking continued until group membership was considered stable and a final allocation of plots to groups was accepted.

Plant ecologists familiar with the vegetation of the area were consulted during the analysis to gauge whether numerical data interpretations matched their perceptions of consistent floristic associations.

Grasslands of the South Eastern Highlands bioregion

Analysis of grassland floristic survey data within the South Eastern Highlands bioregion was carried out through a separate classification process described by Rehwinkel (unpublished). After various data cleaning operations, transformation of cover-abundance scores into a common system, and dealing with taxonomic consistency issues, field data from 437 grassland samples were analysed using the PATN software (Belbin 1995a, 1995b). Grassland classification followed the agglomerative hierarchical fusion strategy, using the Kulczynski measure of association and applying the flexible UPGMA formula with the default Beta value of -0.1. After multiple iterations run to explore the data and potential groups, a final analysis defined eight grassland plant communities (see Rehwinkel unpublished).

Relationship with previous classifications

Relationships between the communities identified by this study and communities identified by overlapping previous broad classifications (i.e. Benson & Jacobs 1994, Gellie 2005, McDougall & Walsh 2007 and Tozer *et al.* 2010) were explored by comparing the assignments of floristic plots to groups between current and previous group definitions. General relationships between the sampling density and classification scale of the current study and the previous broad regional classifications of Gellie (2005) and Tozer *et al.* (2010) were examined in each area of spatial overlap by comparing the numbers of plots classified and the number of separate groups (communities/assemblages) identified from those plots by each study.

Community descriptions

Plant communities identified in this study were labelled with an alpha-numeric code reflecting the dominant origin of that group's definition. Where a plant community corresponded closely with a group defined by a previous study, it was assigned a code reflecting this relationship:

- groups related to alpine communities identified by McDougall & Walsh (2007) are denoted by an 'a' for alps (note that some finer-scale closely related alpine groups were combined here; the code used for the resulting group was based on the original community considered to dominate the composite group);
- communities corresponding with map units described by Tozer *et al.* (2010) retained the alpha-numeric code assigned in that study (prefixes 'e', 'm' and 'p');
- groups closely matching the vegetation groups identified by Gellie (2005) are identified by 'g';
- tableland lake groups identified by Benson & Jacobs (1994) are denoted by 'L'; and
- grassland communities analysed and classified separately by Rehwinkel (unpublished) and described here are identified by an 'r' prefix.

Where an identified community had no clear relationship with any of the groups of previous regional classifications, its alpha-numeric code was prefaced by 'u'.

Plant communities were related to the hierarchy of NSW Structural Formations and Vegetation Classes of Keith (2004) based on their floristic and structural characteristics and the distribution of assigned plots.

Final groups of classified plots were used to characterise the properties of each community. Mean native species richness and cover were calculated from plots allocated to each community, and the vegetation structure of each community was described based on summaries of the structural variable estimates (height and cover for each stratum) recorded for plots within the dataset. The frequency of commonly-occurring weeds within each group was also identified from classified plots. The frequencies of weeds occurring in grasslands classified by Rehwinkel (unpublished) are not known as this separate analysis was undertaken in a dataset only containing native taxa.

Field data were used to generate lists of diagnostic plant taxa for each community and assist with identification in the field. The 'FIDEL' software developed by Bedward (1999) was used to calculate the frequency of each plant taxon within each group and in all other samples in the dataset. These frequency data were used to identify 'positive' and 'constant' diagnostic taxa for each community following the process developed by Tozer (2003) and described by Tozer *et al.* (2010). Positive diagnostic taxa were identified as those which occurred more frequently within a community than in other plant communities (i.e. a hypergeometric probability <0.001). Those taxa occurring with frequency <0.2 within the community and coefficient of variation >0.05 were excluded to minimise the inclusion of unreliable diagnostic taxa. Constant diagnostic taxa were identified as those which occur frequently in the community (>0.4) but also occur frequently in other groups.

Fidelity measures were not calculated for grassland plant communities of the South Eastern Highlands bioregion identified by Rehwinkel (unpublished) as these were described through separate analysis. For these plant communities, cover/abundance and frequency information is presented.

The habitat or broad environmental domain of each community was described based on GIS intersects of plot locations against spatial environmental data including surface geology (DMR undated), soil landscapes (OEH unpublished b), modelled climate layers (Hutchinson 1989, Anon 2009), and topographic variables (altitude, slope, aspect) derived as part of this study from a 25 m grid digital elevation model (LPI 2006). This information was derived from across the broader analysis area, and in some cases augmented by the local knowledge of the authors. Additionally, each plant community contains tabulated summary information on the number of samples, mean species richness, slope, altitude, average annual rainfall and annual temperature range.

Nomenclature

Plant taxonomic nomenclature in this report follows the Australian Plant Census (ANBG 2011). Where the authors were aware of recent accepted taxonomic changes yet to be updated on the Australian Plant Census website, the latest nomenclature was used.

Naming of plant communities follows the format suggested by Benson (2006). For common names this includes one or more of the dominant / diagnostic plant species, the most prevalent structure and height class of upper stratum (based on Walker & Hopkins 1990), a reference to characteristic soil, substrate or climate, and reference to the main geographic occurrence of the plant community such as a location or bioregion. For community scientific names, up to 12 binomial scientific names of characteristic taxa are given, separated into up to three height strata. Alpine communities (i.e. plant communities with a prefix of ‘a’) are treated similarly, although ubiquitous taxa not aiding in plant community diagnosis are not included. Plant communities identified here are considered to fit within the ‘association’ level identified as Level V in Australia’s NVIS hierarchy (ESCAVI 2003).

Results

Field survey and sample distribution

This study collected 319 new full-floristic survey plots. Of these, 270 survey plots targeted remnant woody vegetation within 29 Landscapes considered to have proportionally low existing sampling. A further 49 survey plots sampled vegetation or habitat types perceived to be under-sampled based on reviews of previous plant community classifications and expert knowledge of floristic datasets across the upper Murrumbidgee catchment and surrounds. This additional floristic information enabled greater refinement of floristic definitions for 44 of the 75 plant communities described within the upper Murrumbidgee catchment. Many of the plant communities such as lowland remnant woodland and riparian shrubland communities are of limited extant distribution; the additional survey data increased the sampled distribution range of many plant communities. The surveys also increased sampling in 38 of the 49 Landscapes in the upper Murrumbidgee catchment.

The distribution of survey plots used in the analysis is shown in Figure 4, with Table 4 showing the sampling intensity of Landscapes prior to and after the additional survey. However, strong biases towards areas of public tenure remain and obvious coarse spatial sampling gaps remain on the Monaro plains, the lowlands of the ACT and areas north and west of Yass. Additionally, there are particular habitat types which remain undersampled, including riparian areas and small-scale wetlands.

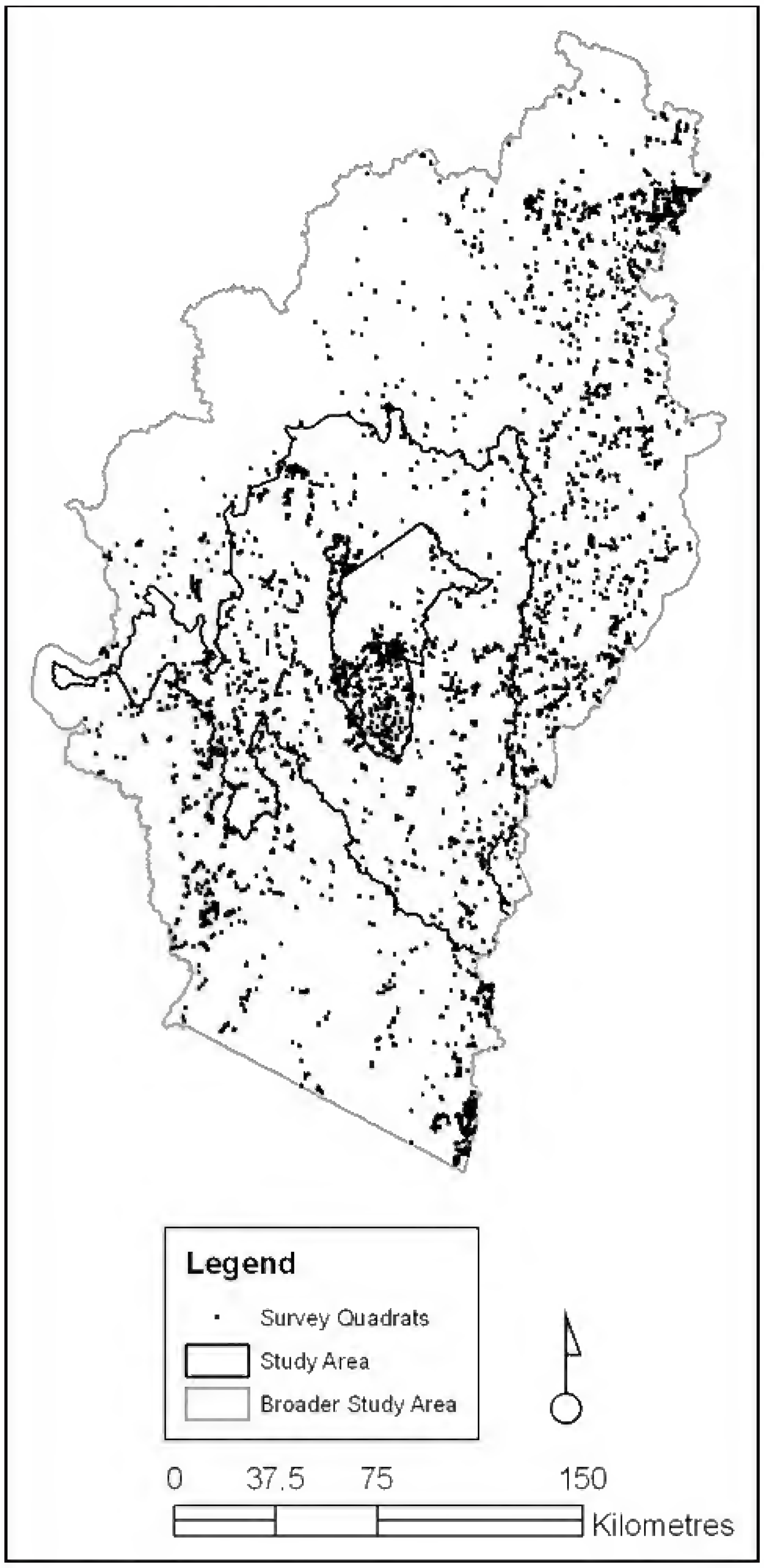

Fig. 4. Distribution of survey plots across the broader analysis area.

Table 4: Plot sampling intensities for each vegetated NSW Landscape within woody vegetation types in the upper Murrumbidgee catchment prior to (pre-study sampling) and collected as part of this study (revised sampling).

			Pre-study sampling			**Revised sampling**	
NSW Landscape	**Area (ha)** [1]	**% vegetated**[2]	**Previous no. of plots**	**Sampling intensity (ha/plot)**	**New plots (this study)**	**Revised total no. of plots**	**Revised sampling intensity (ha/plot)**
Adelong Granite Ranges	21,067	18	6	632	1	7	542
Adrah Hills & Ranges	90,121	23	24	864	0	24	864
Alpine Zone	408	99	11	37	0	11	37
Bogong Montane	1,864	100	2	932	5	7	266
Boorowa Volcanics	74,271	10	10	743	13	23	323
Breadalbane Swamps & Lagoons	11,898	9	2	535	2	4	268
Burrinjuck Ridges	38,982	11	4	1,072	11	15	286
Cabramurra – Kiandra Basalt Caps & Sands	29,049	82	53	449	1	54	441
Canberra Plains	50,986	15	13	588	7	20	382
Carabost Hills & Ranges	16,182	29	1	4,693	0	1	4,693
Coolangubra – Good Good Plateau	164,400	77	118	1,073	6	124	1,021
Cootamundra – Tumut Serpentinite & Ultramafics	6,899	9	4	155	3	7	89
Cullarin Range Fault Block	18,474	31	0	nil	6	6	954
Dalton Hills	132,333	15	42	473	21	63	315
Doura Volcanics	232,494	55	232	551	11	243	526
Gourock – Tindery Ranges	23,753	96	36	633	5	41	556
Gourock – Tindery Slopes	131,114	73	108	886	15	123	778
Gundary Plains	98,550	28	45	613	9	54	511
Gunning Hills	20,299	6	3	406	0	3	406
Jagungal Tops	27,319	99	44	615	1	45	601
Jindabyne Plains	76,936	40	12	2,565	14	26	1,184
Jingera Valley	14,534	32	1	4,651	2	3	1,550
Kings Cross Montane	119,993	99	125	950	22	147	808
Kings Cross Sub-alpine	745	90	0	nil	0	nil	nil
Lake George Complex	46,789	9	7	602	7	14	301
Main Range Sub-alpine	22,951	92	6	3,519	10	16	1,320
Marilba Range	27,284	16	31	141	2	33	132
Minjary Hills & Ranges	70,801	39	52	531	3	55	502
Molonglo Channels & Floodplains	2,934	35	0	nil	6	6	171
Molonglo Ranges	134,740	55	96	772	22	118	628
Monaro Alluvium	2,931	26	0	nil	0	nil	nil
Monaro Lakes	428	32	8	17	0	8	17
Monaro Plains Basalts & Sands	96,295	34	31	1,056	1	32	1,023
Monaro Plains Granites	2,353	46	0	nil	4	4	271
Monaro Plains Meta-sediments	27,928	48	3	4,469	9	12	1,117
Mt Bundarbo Basalt Caps	4,760	28	4	333	0	4	333
Murrumbidgee – Tarcutta Channels & Floodplains	1,461	9	0	nil	1	1	132
Namadgi Range Alpine	14,739	100	53	278	0	53	278
Namadgi Range Montane	121,850	66	198	406	9	207	389
Namadgi Range Sub-alpine	74,816	98	170	431	1	171	429
Oberon – Kialla Granites	5,446	11	4	150	0	4	150
Pinbeyan – Ravine Ranges	28,500	94	14	1,914	17	31	864
Tantangara High Plains & Peaks	33,508	95	20	1,592	17	37	860
Tooma Granite Ranges	140,144	52	102	714	2	104	701
Upper Murrumbidgee Channels & Floodplains	9,598	5	0	nil	6	6	80
Upper Murrumbidgee Gorge	18,365	21	0	nil	8	8	482
Upper Murrumbidgee Valley	40,681	35	12	1,187	23	35	407
Yarrangobilly – Cooleman Karst	3,292	91	14	214	0	14	214
Young Hills & Slopes	100,710	9	34	267	14	48	189

[1] within upper Murrumbidgee catchment plus 10km buffer

[2] Remnant vegetation (% remaining) for entire NSW Landscape. Source: OEH (unpub. a)

Data analysis

Floristic data collected from 4,106 field survey samples met the criteria for inclusion in the analysis. Of these, 738 samples (18%) were not assigned to a final group for various reasons: these were generally identified by high allocation radii (association value) from nearest group centroids, and on detailed inspection were found to include highly disturbed sites; 'mixed' plots including both riparian or wetland taxa and elements of adjacent drier habitats; samples which claimed to be plots but appeared to be random meander lists from a range of habitats with very high species richness; and plots from surveys using species-importance schema that did not transform well to the modified Braun-Blanquet cover-abundance scale used in this study. Grassland sites were not included in the final analysis as these had previously been analysed and classified by Rehwinkel (unpublished).

The remaining 3,368 field samples were assigned to 145 vegetation groups or plant communities across the broader analysis area. Of these, 67 plant communities were recorded within the upper Murrumbidgee catchment or considered likely to occur there. An additional eight grassland communities were identified through the process described by Rehwinkel (unpublished). These 75 plant communities are listed in Table 6 and described in Appendix 1. Coarse floristic relationships between the plant communities identified in this study are indicated by the dendrogram (Figure 5).

Specific relationships between the plant communities identified by this study and those identified by previous numerical classifications (Benson & Jacobs 1994, Gellie 2005, McDougall & Walsh 2007 and Tozer *et al.* 2010) were explored by comparing the assignments of sites to groups between the current study and these previous classifications. The table in Appendix 2 indicates the strongest relationships identified between current and previous classification groups.

The upper Murrumbidgee catchment area overlaps to different extents the classification studies of Gellie (2005) and Tozer *et al.* (2010) and general relationships between the plot clusters identified by this study and the earlier regional classifications were examined. In areas of overlap, the current study utilised all of the field survey plots classified by these previous studies as well as additional recent survey data. The number of groups identified from field survey plots shared by the current and earlier works indicates that Gellie (2005) identified groups at a finer classification scale than the current project [895 shared sites allocated to 75 groups by Gellie (2005) and 67 groups by the current study], while classification by Tozer *et al.* (2010) was at a similar scale to that of the current study (44 shared sites into 13 groups versus 14 groups in the current study). The current study classified an additional 683 field survey plots in the area of overlap with Gellie (2005) and an additional 29 plots in the area of overlap with Tozer *et al.* (2010) (Table 5).

Vegetation distribution

The 75 plant communities identified by numerical analysis from the upper Murrumbidgee catchment [including grasslands identified by Rehwinkel (unpublished)] occur across 18 of the NSW Vegetation Classes within nine of the Structural Formations described by Keith (2004) (Table 6). The sampled distribution of plant communities within each Structural Formation is shown in Figure 6 (refer to Appendix 1 for sampled distribution of each plant community).

Plant communities within the *Alpine Complex* Formation are distributed primarily in higher parts of the Australian Alps bioregion, although there are examples of these communities within montane environments in adjacent areas of the South Eastern Highlands. *Rainforests*, while defined from plots outside of the upper Murrumbidgee catchment, are known to occur in the Bogong Peaks Wilderness Area (Greening Australia 2011). *Wet sclerophyll forests* are generally found in the Brindabella, Namadgi and western fall of the main Kosciuszko range areas in the west, the Tallaganda ranges in the east, and in between at Tinderry NR where a variety of taxa characteristic of both eastern and western wet sclerophyll environments occur. *Dry sclerophyll forests* occur on relatively infertile exposed hills and slopes across most of the study area exclusive of the Kosciuszko main range. *Heathlands* are found on exposed ridges in Dangelong NR in the southeast of the upper Murrumbidgee catchment, and may occur in similar locations. *Forested wetlands* occur primarily on major water courses as narrow remnants on alluvial plains, or surrounded by dry sclerophyll forests in riverine gorges. *Freshwater wetlands* occur in depressions of variable size across the Monaro and in montane areas as bogs and fens. *Grassy woodlands* generally occur as degraded remnants across much of the upper Murrumbidgee catchment (exclusive of the Monaro rain shadow grassland and treeless alpine areas), as small remnants across the highly cleared

Table 5: Comparison of site availability and classification scale in areas of overlap between the upper Murrumbidgee catchment and those of Gellie (2005) and Tozer *et al.* (2010).

Previous Study	Area shared with current study area (ha)	Number of sites classified in this study shared with previous study	Number of groups to which those sites were allocated by each previous study	Number of groups to which those sites were allocated by the current study	Number of sites classified in this shared area by the current study	Number of groups to which those sites were allocated by the current study
Gellie (2005)	1.817,000	932 sites	77 groups	43 groups	1627 sites	68 groups
Tozer *et al.*(2010)	258,000	75 sites	14 groups	16 groups	155 sites	23 groups

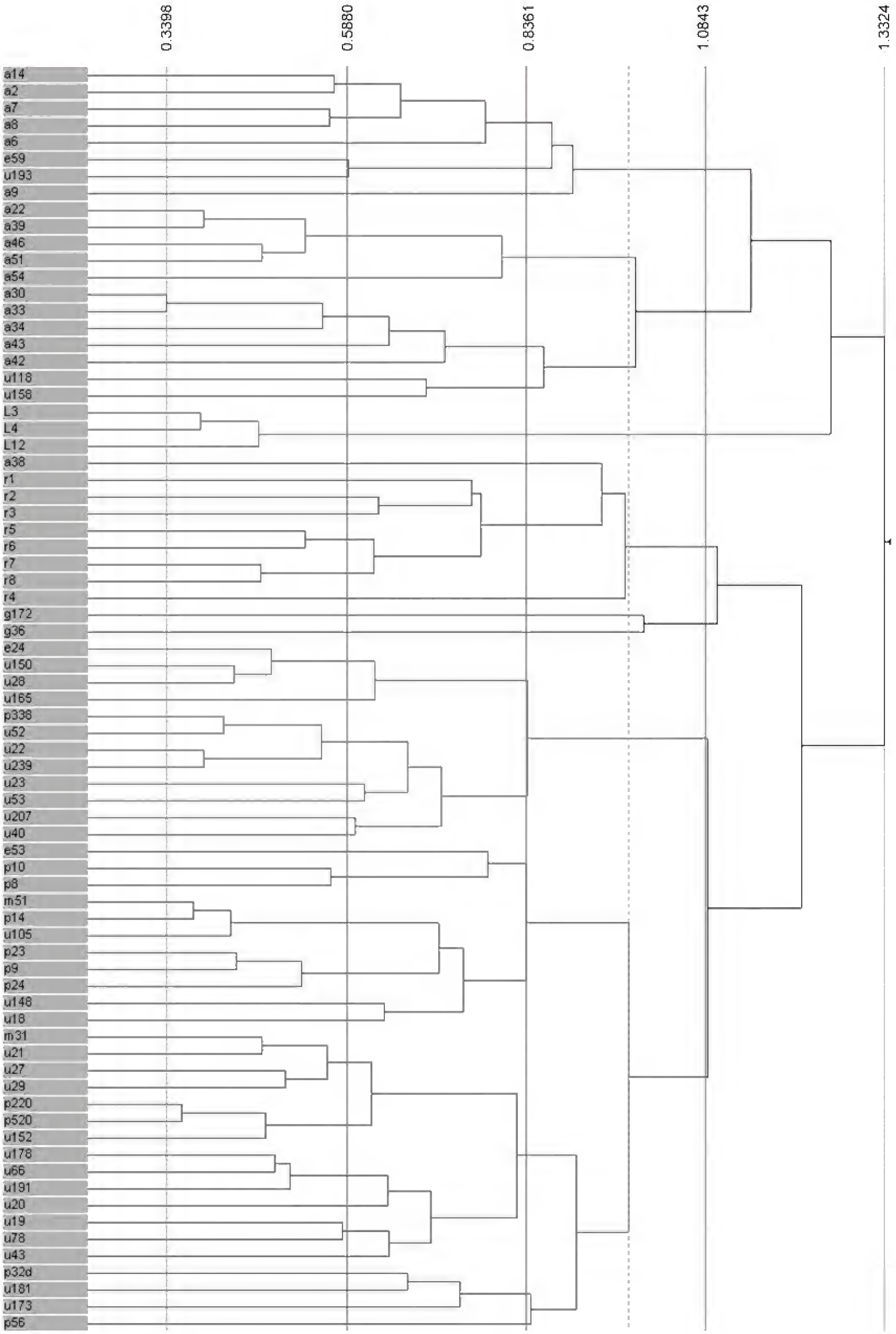

Fig. 5. Dendrogram showing hierarchical relationships between 75 vegetation communities of the upper Murrumbidgee catchment identified from analysis of quantitative survey plot data.

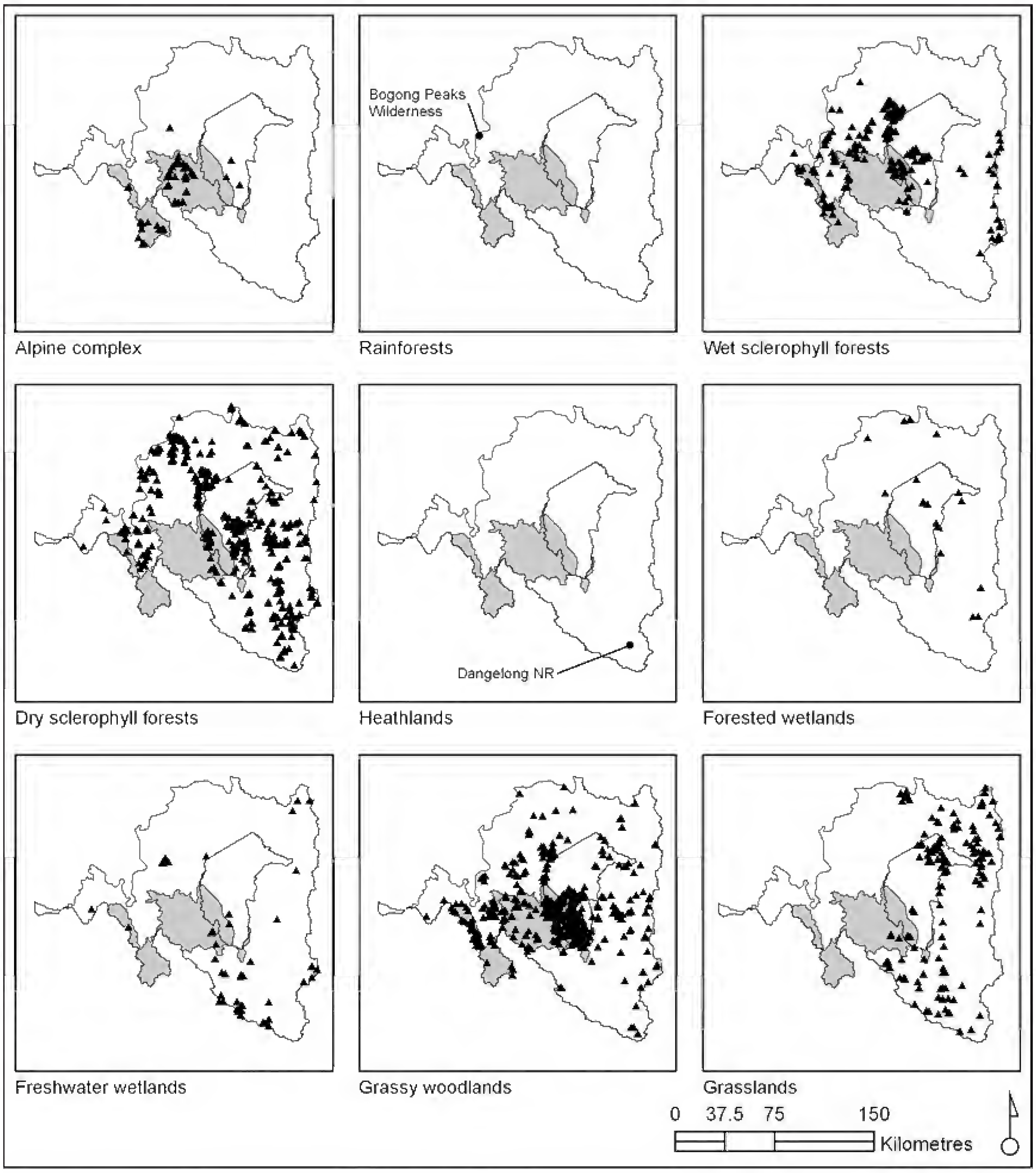

Fig. 6. Distribution of plots occurring within the upper Murrumbidgee catchment area assigned to plant communities in each Structural Formation [Known (rather than sampled) distribution of Rainforest and Heathland also shown; Australian Alps bioregion shaded].

Monaro and Murrumbateman subregions and as patches amongst wet or dry sclerophyll forests. *Grasslands* are known primarily from valleys and depressions influenced by cold air drainage prohibiting tree growth, and on open basalt plains of the Monaro.

Threatened Ecological Communities

Of the 75 plant communities listed in Table 6, four have affinities with Threatened Ecological Communities (TECs) currently listed under the EPBC Act 1999, three with communities listed on schedules of the TSC Act 1995, and two declared under the NC Act 1980 (Table 7).

Discussion

Factors guiding the distribution of plant communities

While producing a vegetation map was beyond the scope of this study, the distribution of plot data provides an indicative distribution of plant communities in the upper Murrumbidgee catchment and surrounds (Figure 6; refer to maps in Appendix 1 for sampled distribution of individual plant communities). The distribution of Structural Formations is generally guided by strong variation in climate (precipitation, temperature and wind), topographic relief (altitude, slope and aspect) and broad lithology. Within each Formation, plant communities are distributed based on finer scale variations of these, along with changes in soil fertility, acidity, frost persistence, water retention and humification. Where relevant, the descriptions of individual plant communities in Appendix 1 include discussion of environmental factors considered likely to be influencing distribution.

Non-floristic factors which may influence vegetation classification

The ability of analytical processes (such as clustering algorithms) to identify recurring plant associations at a consistent classification level can be influenced by variable density or bias in sampling intensity (see Bell 2013), survey timing (e.g. season and precedent wet/dry conditions), sampling effort, species misidentifications and estimation of cover-abundance (see discussion by Tozer *et al.* 2010). The influence of these factors is potentially greatest when particular areas or habitat types are only sampled by one survey or surveyor and there is no alternative source of field data. As outlined in the *Results* section, data lineage and potential bias was considered throughout the analysis to ensure plant communities were not defined based on sampling artefacts. Nevertheless, we have identified some plant communities that are defined primarily on the basis of a single survey. Generally, these plant communities occupy ecological niches subject to specific studies such as treeless alpine areas or wetlands of the Monaro. Three woodland/forest plant communities were also identified on the basis of one survey: u20: *Kurrajong – Bursaria spinosa – Themeda australis shrub-grass mid-high open woodland on limestone karsts in the Wee Jasper area*; u66: *Mealy Bundy – Red Stringybark grass-herb mid-high open forest of the South Eastern Highlands and Upper Slopes Subregion of the South Western Slopes bioregion*; and u191: *Black Cypress Pine – Brittle Gum tall dry open forest on hills primarily in the Cooma region*. Each of these plant communities was identified through data collected in poorly sampled landscapes and dominated by a distinct suite of taxa not characteristic of other plant communities within the broader analysis area. We believe these plant communities are sound but more widespread sampling in similar vegetation will be useful to confirm this and better define relationships with other plant communities.

Numerical classification of plant communities relies on survey plots distributed across the environmental domains considered to govern plant distributions. Plant communities which occur in domains primarily distributed outside a study area may be poorly described, or remain unrecognised, as their full range of variation has not been sampled. For this reason, it is appropriate for vegetation classification studies to include a buffer beyond the study area boundary and include plot samples that assist in adequately identifying and describing such plant communities by incorporating data from across their full environmental domain. In the current study of the upper Murrumbidgee catchment area classification being based on samples from a much larger area of interest, the “broader analysis area” (covering the NSW sections of the Australian Alps and South East Highlands bioregions, from the Victorian border north to the Oberon shire, and the Boorowa Shire). This broader analysis area allowed exploration of relationships between plant communities in the upper Murrumbidgee catchment and the bioregions that it sits within, ensuring that plant communities defined in the upper Murrumbidgee catchment fit within a broader bioregional context.

Differentiation between natural plant communities may also be blurred by widespread disturbance in sampled vegetation, an effect which may be stronger in some plant communities than others. In native vegetation remnants on the tablelands of NSW, for example, disturbance associated with grazing (including selective removal of more durable-timbered tree species, long exclusion of fire, increased soil nitrogen, loss of palatable understorey taxa, invasion by exotic plants and selective grazing of more palatable herbs) (e.g. see Leigh & Holgate 1979; Prober & Thiele 2005) may lead to simplification of structure and composition and consequent blurring of floristic differences between related plant communities. In the current study, plant communities associated with landscapes of high to moderate agricultural suitability are likely to be most prone to classification blurring, such as vegetation of moist alluvium, grassy woodlands and grasslands of undulating tableland and slopes landscapes.

The ability of numerical classification to identify plant associations at a consistent classification level can also be influenced by plot size. Otýpková & Chytrý (2006) found that variation in plot size affected the ability of ordination techniques to identify stable groups and potentially distorted plant community group clustering in ordination. Two plots sampling the same plant community with widely different plot sizes may have reduced association or similarity values simply because a larger plot may include taxa absent from the smaller plot. The effect of plot size on ordination was not tested as part of this study, rather floristic information was reviewed to exclude plots that were considered unusual (e.g. likely to be sampling across an ecotone or collected through random-meander). Plot size could be dictated at a Structural Formation classification level (or a similar broad classification) to guide appropriate plot size relative to functions of scale and floristic variation. For example, McDougall (1978) found that a plot size of 8 m^2 was sufficient to capture 95% of species in a diverse open heathland on the Bogong High Plains in the Australian Alps bioregion in Victoria. Neldner & Butler (2009) suggest that, in Queensland, the rate of new species being encountered in rainforests did not decline until about 2,000 m^2 had been sampled.

In the present study, variable plot size was potentially a strong influence in the identification of tableland lake plant communities. The majority of samples from this habitat available to the present study (65 out of 76) were whole-lake samples by Benson & Jacobs (1994), recording all plant taxa from both the strandline margin and standing water of each lake surveyed. Lakes ranged in size from less than 1 ha up to 215 ha, with a median size of over 5 ha. In contrast, the 11 more recent lake samples involved 0.04 ha plots, generally located in standing water parts of wetlands. In the cluster analysis, the Monaro lake samples showed a clear tendency

Table 6: Plant communities occurring in the upper Murrumbidgee catchment area, and their relationship with the Vegetation Classes and Structural Formations of Keith (2004).

ALPINE COMPLEX

Class: Alpine Herbfields

a6: *Ranunculus millanii – Pratia surrepens – Carex gaudichaudiana* herbfield of shallow depressions in the Australian Alps bioregion
a14: *Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion
a22: *Poa fawcettiae – Celmisia costiniana – Craspedia maxgrayi* grassland of the Australian Alps bioregion
a30: *Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola* grassland of the Australian Alps bioregion
a38: *Themeda australis – Galium roddii – Leucochrysum alpinum* grassland of steep limestone slopes in the Australian Alps bioregion

Class: Alpine Heaths

a33: *Bossiaea foliosa – Cassinia monticola – Kunzea muelleri – Hovea montana* heathland of the Australian Alps bioregion
a39: *Epacris* sp. – *Pentachondra pumila – Poa fawcettiae* heathland of the Australian Alps bioregion
a42: *Epacris celata – Poa clivicola – Dillwynia palustris* grassy heathland of the Australian Alps bioregion
a43: *Bossiaea riparia – Themeda australis* low open heathland of the Australian Alps bioregion
a46: *Prostanthera cuneata – Orites lancifolius – Nematolepis ovatifolia* heathland of the Australian Alps bioregion
a51: *Podocarpus lawrencei – Rytidosperma alpicola – Brachyscome nivalis* low open heathland of rock outcrops of the Australian Alps bioregion
a54: *Podocarpus lawrencei – Pimelea ligustrina* subsp. *ciliata* heathland of screes and boulder-fields of the Australian Alps bioregion
g36: *Leptospermum micromyrtus – Kunzea muelleri – Kunzea ericoides* dry heathland on skeletal ridges primarily of the Namadgi region

Class: Alpine Bogs and Fens

a2: *Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum* wet heathland of the Australian Alps bioregion (Bog)
a7: *Ranunculus pimpinellifolius – Gonocarpus micranthus* herbfield of wetland margins in the Australian Alps bioregion
a8: *Carex gaudichaudiana – Myriophyllum pedunculatum – Deschampsia cespitosa* sedgeland of the Australian Alps bioregion (Fen)

RAINFORESTS

Class: Cool Temperate Rainforests

g172: Black Sassafras temperate rainforest of wet sheltered slopes in the Australian Alps and Bondo subregion of the South Eastern Highlands bioregions

WET SCLEROPHYLL FORESTS

Class: Montane Wet Sclerophyll Forests

u40: Alpine Ash very tall wet sclerophyll open forest primarily of the Australian Alps bioregion
u53: Mountain Gum – Blackwood tall wet sclerophyll open forest primarily on granitoids of the Australian Alps and western South Eastern Highlands bioregions
u239: Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions

Class: Southern Tableland Wet Sclerophyll Forests

u52: Ribbon Gum – Robertson’s Peppermint very tall wet sclerophyll open forest primarily of the Bondo subregion of the South Eastern Highlands and the northern Australian Alps bioregions

Class: Southern Escarpment Wet Sclerophyll Forests

p338: Brown Barrel wet sclerophyll very tall grass-herb open forest primarily of the Gourock and Tallaganda Ranges in the South Eastern Highlands bioregion

DRY SCLEROPHYLL FORESTS

Class: Southern Tableland Dry Sclerophyll Forests

e24: Mountain Gum – Snow Gum very tall dry shrubby open forest primarily in the Kybeyan – Gourock subregion of the South Eastern Highlands bioregion
m31: Ribbon Gum – Snow Gum – *Cassinia longifolia* tall shrub-grass open forest of gullies in quartz-rich ranges in the Monaro and Kybeyan-Gourock subregions of the South Eastern Highlands bioregion
m51: Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll open forest on exposed quartz-rich slopes and ridges at primarily in the Monaro and Kybeyan – Gourock subregions of the South Eastern Highlands bioregion
p8: Silvertop Ash – Narrow-leaved Peppermint shrubby tall dry open forest primarily on sedimentary ridges of the eastern South Eastern Highlands bioregion
p10: Black She-oak – Silvertop Ash tall shrubby dry sclerophyll open forest primarily in the Bungonia subregion of the South Eastern Highlands bioregion
p9: Brittle Gum – Scribbly Gum shrubby tall dry open forest on infertile low ridges and hills primarily of the Bungonia subregion of the South Eastern Highlands bioregion
p14: Red Stringybark – Scribbly Gum – *Rytidosperma pallidum* tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion
p23: Red Stringybark – Broad-leaved Peppermint tall dry sclerophyll grassy open forest on loamy rises primarily in the Bungonia subregion of the South Eastern Highlands bioregion
u18: Mealy Bundy – Broad-leaved Peppermint shrubby mid-high open forest on granite substrates primarily in the South Eastern Highlands
u21: Broad-leaved Peppermint – Candlebark tall dry sclerophyll open forest of quartz-rich ranges of the upper South East Highlands and lower Australian Alps bioregions
u29: Apple Box – Broad-leaved Peppermint tall shrub-grass open forest primarily on granitoids of the South Eastern Highlands bioregion
u105: Broad-leaved Peppermint – Brittle Gum – Red Stringybark tall shrub-grass dry sclerophyll open forest of lower ranges of the western South Eastern Highlands and upper South Western Slopes bioregions
u148: Red Stringybark – Red Box grass-forb tall open forest of the upper South Western Slopes and western South Eastern Highlands bioregions
u150: Broad-leaved Peppermint – Mountain Gum shrubby tall open forest of the South Eastern Highlands and Australian Alps bioregions
u152: Robertson's Peppermint – Red Stringybark very tall grass-forb sheltered open forest of the southwest South Eastern Highlands and upper South Western Slopes bioregions
u165: Robertson's Peppermint very tall shrubby open forest primarily of the Bondo subregion of the South Eastern Highlands bioregion
u191: Black Cypress Pine – Brittle Gum tall dry open forest on hills primarily in the Cooma region

Class: Upper Riverina Dry Sclerophyll Forests

u43: Mealy Bundy – *Acacia implexa – Allocasuarina verticillata – Ricinocarpos bowmanii* tall grassy open woodland on serpentinite in the Coolac-Goobarragandra area primarily of the upper South Western Slopes bioregion
u66: Mealy Bundy – Red Stringybark grass-forb mid-high open forest of the South Eastern Highlands and Upper Slopes Subregion of the South Western Slopes bioregion

HEATHLANDS

Class: Southern Montane Heaths

e53: *Allocasuarina nana* shrubland on exposed skeletal ridges of primarily in the eastern South Eastern Highlands bioregion

FORESTED WETLANDS

Class: Eastern Riverine Forests

p32d: River She-oak riparian forest on sand/gravel alluvial soils along major watercourses of the South Eastern Highlands and upper South Western Slopes bioregions
p56: *Leptospermum grandifolium – Hakea microcarpa – Lomatia myricoides* riparian very tall shrubland of the eastern South Eastern Highlands bioregion
u181: *Callistemon sieberi – Kunzea ericoides* rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes bioregions

FRESHWATER WETLANDS

Class: Inland Riverine Forests

u173: River Red Gum ± Apple Box very tall grass-forb riparian woodland on alluvial flats in the South Eastern Highlands and upper South Western Slopes bioregions

Class: Montane Bogs and Fens

a9: *Carex gaudichaudiana – Ranunculus amphitrichus – Phragmites australis* aquatic herbfield of waterways in the Australian Alps and South Eastern Highlands bioregions
e59: *Hakea microcarpa – Baeckea utilis – Leptospermum myrtifolium* subalpine wet heathland on escarpment and eastern tableland ranges of the South Eastern Highlands bioregion
u193: *Hakea microcarpa – Epacris breviflora – Epacris paludosa* subalpine wet heathland of the Australian Alps and western South Eastern Highlands bioregions

Class: Montane Lakes

L12: Freshwater sedge-herb marsh of shallow, commonly inundated wetlands of the eastern South Eastern Highlands bioregion
L3: Freshwater sedge-herb marsh of shallow ephemeral lakes of the eastern South Eastern Highlands bioregion
L4: Freshwater sedge-herb marsh of deep semi-permanent and/or slightly saline wetlands of the eastern South Eastern Highlands bioregion

GRASSY WOODLANDS

Class: Subalpine Woodlands

a34: Weeping Snow Gum shrub-grass open woodland of the Australian Alps bioregion
u22: Mountain Gum – Snow Gum ± Robertson's Peppermint grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions
u23: Snow Gum – Drumstick Heath – *Leptospermum myrtifolium* tall woodland to open forest of drainage depressions primarily of the South Eastern Highlands bioregion
u27: Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion
u28: Snow Gum – Mountain Gum – *Daviesia mimosoides* tall dry grass-shrub subalpine open forest of the Australian Alps and South Eastern Highlands bioregions
u118: Black Sallee grass-herb woodland in drainage depressions and moist valley flats in the South Eastern Highlands and Australian Alps bioregions
u158: Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion
u207: Jounama Snow Gum – Snow Gum shrubby mid-high woodland on granitoids primarily of the Namadgi region

Class: Southern Tableland Grassy Woodlands

p24: Yellow Box – Blakely's Red Gum tall grassy woodland on undulating sedimentary and acid-volcanic substrates in the Goulburn area of the South Eastern Highlands bioregion
u19: Blakely's Red Gum – Yellow Box ± White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands bioregions
u20: Kurrajong – Bursaria spinosa – Themeda australis shrub-grass mid-high open woodland on limestone karsts in the Wee Jasper area
u178: Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands bioregion

Class: Tableland Clay Grassy Woodlands

p220: Ribbon Gum – Snow Gum tableland flats tall grassy woodland primarily on granitoids in the Kybean – Gourock and Monaro subregions of the South Eastern Highlands bioregion
p520: Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion
u78: Snow Gum grassy mid-high woodland of the South Eastern Highlands bioregion

Class: Temperate Montane Grasslands

r1: Sub-montane moist tussock grassland of the South Eastern Highlands bioregion
r2: Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion
r3: Rytidosperma sp. – Themeda australis – Juncus sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion
r4: Lacustrine Grass-forbland of the South Eastern Highlands bioregion
r5: Rytidosperma sp. – Austrostipa bigeniculata – Chrysocephalum apiculatum tussock grassland of the South Eastern Highlands bioregion
r6: Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion
r7: Themeda australis – Rytidosperma sp. – Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion
r8: Themeda australis – Lomandra filiformis – Aristida ramosa dry tussock grassland in the South Eastern Highlands bioregion

to form three main groups identified by Benson & Jacobs (1994), with minor shifts in group membership. The newer 0.04 ha plot samples showed a moderate tendency to join the larger Monaro groups; as there were no strong differences in elevation, substrate or other factors to justify a separation between the wetland vegetation sampled by newer plots and the Monaro whole-lake wetland samples, the plot samples were assigned to the Monaro groups. Further sampling and clarification of tableland lake communities using a consistent set of methods is desirable, particularly as larger lake systems with variable water depth may contain more than one plant community.

Relationships with overlapping previous regional classifications

Based on comparisons of group memberships, the plant communities identified by the current study show varying relationships with groups identified by previous studies (Appendix 2). The treeless alpine plant communities identified by McDougall & Walsh (2007) are largely retained in the current study, with some merging of related types reflecting a somewhat broader classification scale applied by the current study, and the absence of Victorian plots in the analysis. The tableland lake communities identified by Benson & Jacobs (1994) are also essentially retained, with two highly similar types merged. Many of the plant communities identified in the east of the current study area have clear relationships with the associations identified by Tozer *et al.* (2010), however some are described in the context of the broader analysis area based on inclusion of a larger pool of tableland samples than was available to that study, and to some extent, a different study area context. In the central and western parts of the upper Murrumbidgee catchment, relationships between plant communities of the current study and the vegetation groups of Gellie (2005) are far more complex, with few close equivalents. This different relationship may be attributable to the different classification scales adopted, and to the significant additional field survey data available to the current study both within areas of overlap and extending beyond previous study boundaries (see Table 5).

The reader should be aware that two communities with the same identifier in different classifications may have a different diagnostic species list in each. This may be caused by the additional plots available to the current study or differences in study area boundaries. For instance, plant community p14 in the current classification contains 101 of 154 plots used by Tozer *et al.* (2010) to define map unit p14 in that study, and an additional 64 plots that were not used in the original classification. Map unit p14 as defined by Tozer *et al.* (2010) and p14 as described in this study are likely to be equivalent, given the dominance of plots used in the initial classification and the similarity in diagnostic species. Similarly, Community p520 as described in Tozer *et al.* (2010), while considered equivalent to p520 in this study, contains a higher frequency of *Eucalyptus pauciflora* ssp. *pauciflora,* with less *Eucalyptus stellulata.*

The effect of spatial context is especially strong when considering plant communities occurring on the edge of the broader analysis area. For example, the broader analysis area of the current study overlaps the study area of Tozer *et al.* (2010) to the east and north, and a number of eastern escarpment and central tablelands vegetation types identified by that study are peripheral to the broader analysis area, with just a small portion of their distribution overlapping. Of the 30 field samples allocated to map unit e11 [*Tantawangalo Wet Shrub Forest*] by Tozer *et al.* (2010), only one was in the broader analysis area; of 131 samples of p40 [*Temperate Dry Rainforest*], three were in the broader analysis area; and of 125 samples allocated by Tozer *et al.* (2010) to p144 [*Wingecarribee-Burragorang Sandstone Forest*], only two were in the broader analysis area. Where the majority of an original group's membership was outside the broader analysis area, samples were automatically allocated to the

Table 7: Relationships between plant communities described in this study and Threatened Ecological Communities under Commonwealth, NSW and ACT legislation.

Threatened Ecological Community	Legislation	Plant community
Alpine Sphagnum Bogs and Associated Fens	EPBC Act 1999	a2, a8
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions	TSC Act 1995	a2, a7, a8, e59, u193
Natural Temperate Grassland	NC Act 1980	r1, r2, r3, r5, r7, r8
Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory	EPBC Act 1999	r1, r2, r3, r4, r5, r6, r6, r8
Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions	TSC Act 1995	u27, u118, p220, p520, u78 (all); e24, m31, u21, u22, u23, u28 (may contain)
Upland Wetlands of the New England Tablelands and the Monaro Plateau	EPBC Act 1999	L12, L3, L4
White Box Yellow Box Blakely's Red Gum Woodland	TSC Act 1995	p24, u19, u178 (all); p23, u20 (may contain)
White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derived Native Grassland	EPBC Act 1999	p24, u19, u178 (all); p23, u20 (may contain)
Yellow Box/Red Gum Grassy Woodland	NC Act 1980	r178, u19

group identified by Tozer *et al.* (2010). However, none of these plant communities occur in the upper Murrumbidgee catchment.

The large number of endemic species in plant communities in the Australian Alps means that diagnostic taxa may be identified for these communities simply because they do not occur in non-Alps communities. The diagnostic taxa are therefore useful for distinguishing Alps communities from non-Alps communities but not necessarily for distinguishing Alps communities from each other. We suggest that users attempting to identify Alps communities place less value on species that are diagnostic in many Alps communities (e.g. *Carex gaudichaudiana, Poa costiniana, Grevillea australis*) and make decisions based on the presence of many taxa from the diagnostic species list.

The diagnostic species lists in this paper will aid plant community identification within the upper Murrumbidgee catchment but should not be used to identify the same communities beyond. When a seamless plant community classification is produced for NSW, the floristic character of the resulting communities, which will be based on all available data and their entire extent, may be subtly different from the current and previous classifications.

The method for identifying diagnostic taxa in this study has been used in several plant community classifications in NSW. Experience from this study suggests that development of a less context-sensitive measure of fidelity (the basis for the identification of diagnostic taxa), is desirable for large regional classifications. Alternative metrics are presented by De Cáceres *et al.* (2008).

Threats to plant communities

Whilst legislation [e.g. *Native Vegetation Act 2003* (NSW) and the *Planning and Development Act 2007*(ACT)] has reduced the threat of broad scale clearing in NSW and the ACT, many of the plant communities described in this study are subject to ongoing threats. Land-clearing, stock and feral herbivore grazing, weed invasion, altered hydrology, climate change and alteration of fire regimes continue to significantly reduced the distribution, floristic integrity and genetic variability of vegetation across the landscape (Keith & Auld 2009). This is evident in the majority of plant communities within the upper Murrumbidgee catchment, and perhaps more so in *Grassy Woodlands*, *Grasslands*, *Forested Wetlands* and *Freshwater Wetlands* Formations occurring in highly altered landscapes at lower elevations. Many *Dry Sclerophyll Forests*, *Wet Sclerophyll Forests* and *Heathlands* are relatively well protected in the formal reserve system or managed on Forests NSW estate. Plant communities in the *Alpine Complex* are, for the most part, well protected in the formal reserve system. However, even in the Alps, changes in vegetation distribution and functionality are likely to occur due to increased temperatures, decreased precipitation and decreased duration of snow cover related to anthropogenic climate change (Pickering & Armstrong 2003). *Rainforests*, while formally reserved and small in extent, need to be protected from extreme fire events. The scale of threat to all plant communities identified in this study and the adequacy of protection can only be assessed once mapping and detailed threat analysis has been completed.

Nine Threatened Ecological Communities (TEC) under Commonwealth, NSW and ACT legislation occur in the upper Murrumbidgee catchment (Table 7). This study has also identified five additional plant communities which are highly restricted in distribution and may require active management or protection to ensure their survival. Community g172 [*Black Sassafras temperate rainforest of wet sheltered slopes in the Australian Alps and Bondo subregion of the South Eastern Highlands bioregions*] is found in isolated patches along creeks in the Bogong Peaks wilderness area, Geehi Valley, and Jacobs and Pinch River Gorges. It occurs in small and potentially genetically isolated patches which, to date, have escaped severe wildfires (Doherty *et al.* 2011, Greening Australia 2011). Community u20 [*Kurrajong – Bursaria spinosa – Themeda australis shrub-grass mid-high open woodland on limestone karsts in the Wee Jasper area*] is highly restricted, believed to have approximately 10 ha remaining and contains a number of threatened and unusual plant taxa. Community u43 [*Mealy Bundy – Acacia implexa – Allocasuarina verticillata – Ricinocarpos bowmanii tall grassy open woodland on serpentinite in the Coolac–Goobarragandra area primarily of the upper South Western Slopes bioregion*] is restricted in distribution, and is highly fragmented with little recruitment of woody species observed within sampled areas. Community u173 [*River Red Gum ± Apple Box very tall grass-forb riparian woodland on alluvial flats in the South Eastern Highlands and upper South Western Slopes bioregions*] occurs on fertile alluvial flats adjacent to major rivers and has been extensively cleared, with isolated remnants commonly degraded by grazing and weed invasion. Community a54 [*Podocarpus lawrencei – Pimelea ligustrina subsp. ciliata heathland of screes and boulder-fields of the Australian Alps bioregion*] is highly restricted and the primary habitat of the endangered Mountain Pygmy Possum. Most examples of community a54 in NSW were burnt in 2003, with the dominant species of this species-poor community (*Podocarpus lawrencei*) sensitive to fire (McDougall *et al.* 2012), potentially taking a decade or more to be reproductive. These communities should be assessed for eligibility for protection under State and/or Commonwealth legislation.

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r5: Rytidosperma sp. – Austrostipa bigeniculata – Chrysocephalum apiculatum tussock grassland of the South Eastern Highlands bioregion
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r7: Themeda australis – Rytidosperma sp. – Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion
r8: Themeda australis – Lomandra filiformis – Aristida ramosa dry tussock grassland in the South Eastern Highlands bioregion

Plant community type descriptions

Additional to text descriptions, tabulated floristic information, photographs and figures, each plant community contains tabulated summary information as follows:

Number of samples: Number of field samples assigned to a particular community and used to characterise species composition and habitat.

Richness [mean (±SD)]: Average richness of native species per plot sample within a particular plant community (± 1 standard deviation).

Slope (degrees): Approximate ground surface slope of samples assigned to a particular plant community, as: [(minimum) 25th percentile – 75th percentile (maximum)] (from GIS; sample intersect with slope surface generated from 25m digital elevation model).

Altitude (m asl): Approximate elevation of samples assigned to a particular plant community, as [(minimum) 25th percentile – 75th percentile (maximum)] (from GIS; sample intersect with elevation surface generated from 25m DEM).

Ave. Annual Rainfall (mm): Modelled average annual rainfall of plots assigned to a particular plant community, as [(minimum) 25th percentile – 75th percentile (maximum)] (from GIS; sample intersect with climate surface generated using BioClim software).

Temp. Annual Range (°C): Modelled annual temperature range (mean maximum of warmest month minus mean minimum of coldest month) of samples assigned to a particular plant community, as [(minimum) 25th percentile – 75th percentile (maximum)] (from GIS; sample intersect with climate surface generated using BioClim software).

Formation: Alpine Complex

Class: Alpine Herbfields

a6: *Ranunculus millanii – Lobelia surrepens – Carex gaudichaudiana* herbfield of shallow depressions of the Australian Alps bioregion

Scientific Name: *Ranunculus millanii – Lobelia surrepens – Carex gaudichaudiana – Dichondra repens – Hydrocotyle sibthorpioides – Gonocarpus micranthus*

Number of samples:	5
Richness [mean (±SD)]:	11 (4)
Slope (degrees):	(1) 2–3 (6)
Altitude (m asl):	(1156) 1268–1302 (1527)
Ave. Annual Rainfall (mm):	(1037) 1123–1564 (1590)
Temp. Annual Range (°C):	(22.2) 23.3–24.2 (24.3)

Vegetation Description: Community a6 is a wet low sedgeland/herbfield with characteristic species including *Lobelia surrepens*, *Ranunculus millanii*, *Gonocarpus micranthus*, *Isolepis montivaga*, *Myriophyllum pedunculatum*, *Stackhousia pulvinaris* and *Lachnagrostis meionectes*.

Plate a6: A depression in *Poa fawcettiae* grassland, the habitat of community a6; this example near Spencers Creek, Kosciuszko NP. The flora of this community is distinct from that of surrounding communities only a few cm away. The depressions are often water-filled in spring and late autumn.

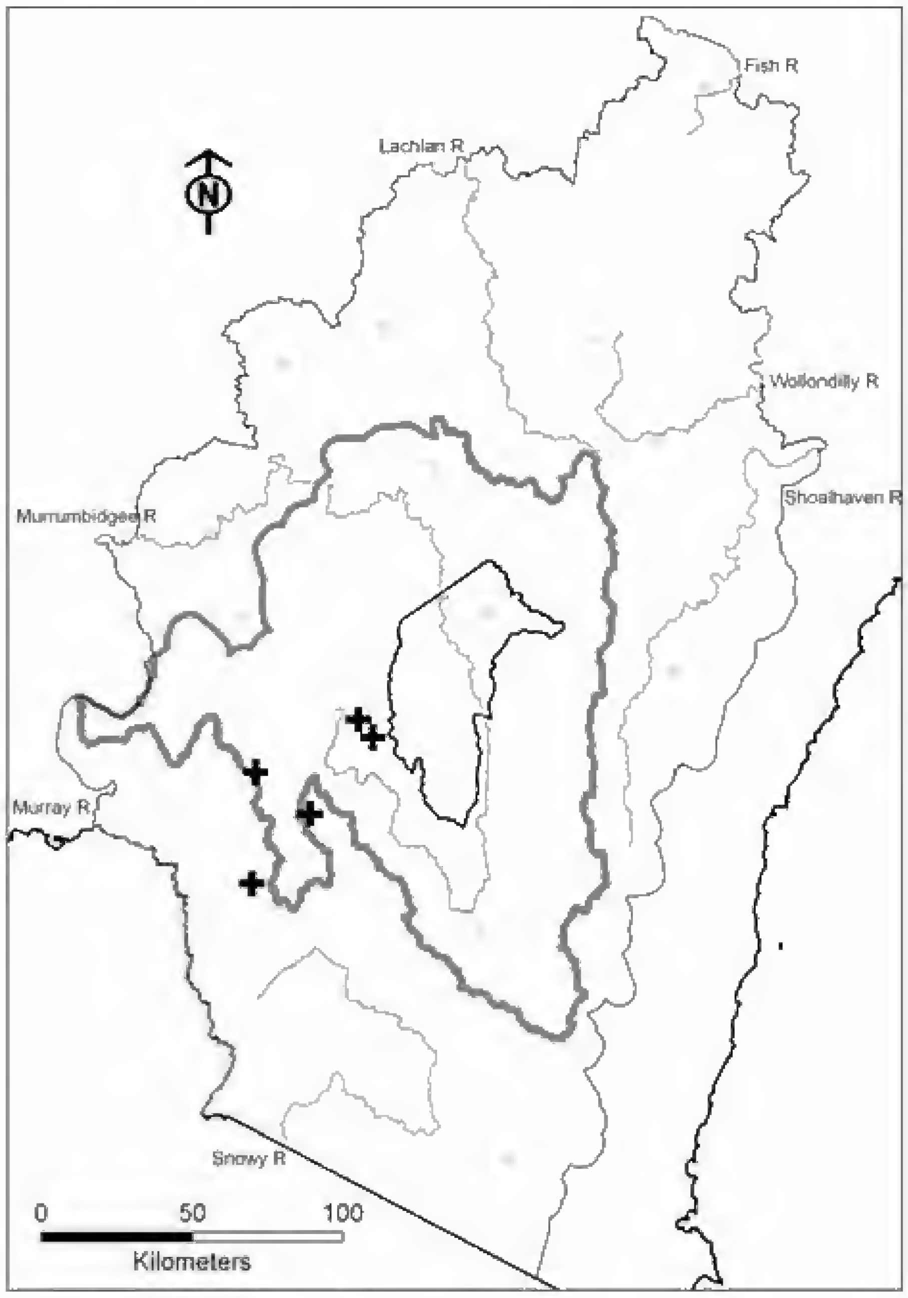

Fig. a6: Distribution of field samples assigned to plant community a6.

Carex gaudichaudiana is usually present, particularly in deeper sections of the depressions where water tends to persist for longer periods.

This community occurs on the Bimberi Range (ACT), northern Kosciuszko NP and surrounds (e.g. Kiandra, Seventeen Flat, Broadway Plain, McPhersons Plain and Cooleman Plain) and a number of sites of suitable topography in Victoria where it is locally common. It is confined to, and highly characteristic of, seasonally inundated depressions of alpine and high subalpine areas. There appears to be no convincing explanation for the genesis of these formations. The depressions may be more or less linear and oriented across slopes or they may be nearly circular on almost flat ground. They are underlain by water-retentive soils, often derived from igneous parent material, and filled with water following snow-melt. By early summer they are usually empty of surface water, but soils remain moist through the season (sometimes filling again during heavy rains).

Individual examples of Community a6 are often only a few square metres in area, but there will generally be many within a grassland stand. The main grassland community in which this is expected is Community a30 [*Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion*]. Less commonly, it is found amongst grassy heathland, such as Community a42 [*Epacris celata – Poa clivicola – Dillwynia palustris grassy heathland of the Australian Alps bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Carex chlorantha	3	40	1	<1	P
Carex gaudichaudiana	3	100	2	4	P
Dichondra repens	1	80	2	21	P
Gonocarpus micranthus	3	60	1	2	P
Hydrocotyle sibthorpioides	2	80	2	4	P
Hypericum japonicum	2	40	1	4	P
Isolepis fluitans	1	20	2	<1	P
Isolepis montivaga	1	20	1	<1	P
Isolepis spp.	1	40	1	<1	P
Juncus brevibracteus	1	40	1	<1	P
Lobelia surrepens	3	80	2	<1	P
Luzula alpestris	1	20	1	<1	P
Myriophyllum pedunculatum	1	20	1	<1	P
Plantago alpestris	1	20	1	<1	P
Plantago antarctica	1	20	1	<1	P
Pultenaea fasciculata	1	20	1	<1	P
Ranunculus millanii	2	80	1	<1	P
Spiranthes australis	1	20	1	<1	P
Asperula gunnii	1	40	1	5	C
Viola betonicifolia	1	60	1	27	C

Threatened communities: Nil.

Equivalent vegetation types: Unit 8A [*Pratia depression*] and Unit 8B [*Fen (Bog pool)*] (McDougall 1982); *Damp alpine heathland* Sub-community 10.1 (Walsh *et al.* 1984); Vegetation Type 9 (Helman & Gilmour 1985); Community 6 [*Lobelia surrepens – Ranunculus millanii herbfield*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.20), *Poa pratensis* (0.20), *Rorippa palustris* (0.20), *Rumex conglomeratus* (0.20), *Taraxacum officinale* (0.20), *Trifolium repens* (0.20).

Threats: Trampling by livestock or feral horses may damage plants or soils but the threat is currently low.

Reservation status: Mostly in Kosciuszko NP as well as Namadgi NP, but some examples are on freehold or leasehold land west of Kosciuszko NP.

Extent of clearing: Nil.

References: Helman, C.E. & Gilmour, P.M. (1985) Treeless vegetation above 1,000 metres altitude in the A.C.T. Unpublished report. Conservation Council of the Southeast Region and Canberra: Canberra; McDougall, K.L. (1982) The alpine vegetation of the Bogong high plains. Environmental studies publication no. 357. Ministry for Conservation: Melbourne; McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; Walsh, N.G., Barley, R.H. & Gullan, P.K. (1984) The alpine vegetation of Victoria (excluding the Bogong high plains), volume 1. Environmental studies publication no. 376. Department of Conservation, Forests and Lands: Melbourne.

a14: *Poa costiniana – Carex gaudichaudiana* subalpine valley grassland of the Australian Alps bioregion

Scientific Name: *Poa costiniana – Carex gaudichaudiana – Stellaria angustifolia – Asperula gunnii – Luzula modesta*

Number of samples:	23
Richness [mean (±SD)]:	18 (6)
Slope (degrees):	(0) 1–6 (14)
Altitude (m asl):	(1008) 1237–1434 (1618)
Ave. Annual Rainfall (mm):	(807) 1082–1468 (1912)
Temp. Annual Range (°C):	(21.7) 22.8–24.5 (26.1)

Vegetation Description: Community a14 is a grassland or occasionally open heathland confined to broad valley floors and seepage areas on gentle slopes. Dominant species vary between localities, but common components include herbaceous species such as *Poa costiniana*, which is usually dominant, *Hookerochloa hookeriana*, *Baloskion australe*, *Carex gaudichaudiana*, *Empodisma minus* and *Stylidium montanum* as well as shrubs including *Epacris breviflora*, *Epacris gunnii* and *Hakea microcarpa*. In the northern part of its range, including the ACT, *Poa labillardierei* is often dominant. Soils are typically sodden humified peats.

Community a14 is common from Bimberi, Brindabella and Scabby Ranges (ACT), through lower altitude plains within Kosciuszko NP (Kiandra and Tantangara areas, Mt. Selwyn, Tooma/Tumut Divide, Cooleman Plain, Happy Jacks Plain and Currango Plain). It also occurs in the more easterly ranges of Victoria (e.g. Mt. Wombargo-Cobberas area, Nunniong Plateau, Davies Plain and Dinner Plain). It commonly grades into Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*] in areas with impeded drainage and Community a30 [*Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion*] on drier sites.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Asperula gunnii	1	74	1	4	P
Baloskion australe	1	30	1	2	P
Brachyscome decipiens	1	26	1	2	P
Brachyscome obovata	1	30	1	<1	P
Cardamine astoniae	1	39	1	<1	P
Carex gaudichaudiana	2	91	2	3	P
Carex jackiana	1	26	1	<1	P
Cassinia monticola	1	22	1	1	P
Craspedia crocata	1	22	2	<1	P
Empodisma minus	2	52	2	3	P
Epacris gunnii	1	35	1	2	P
Epilobium billardierianum	1	39	1	2	P
Epilobium gunnianum	1	43	1	1	P
Hookerochloa hookeriana	2	26	1	<1	P
Hydrocotyle algida	1	22	1	<1	P

Hypericum japonicum	1	39	1	3	P
Luzula modesta	1	61	1	2	P
Montia australasica	1	35	1	1	P
Oreomyrrhis ciliata	1	43	1	2	P
Poa costiniana	4	100	2	4	P
Ranunculus graniticola	1	48	1	4	P
Ranunculus millanii	1	30	2	<1	P
Ranunculus pimpinellifolius	1	35	1	1	P
Senecio gunnii	1	39	1	9	P
Stellaria angustifolia	1	61	1	1	P

Threatened communities: Nil

Equivalent vegetation types: part of *Poa caespitosa – Danthonia nudiflora* alliance (Costin 1954); *Damp alpine heathland*, Sub-community 10.3 (Walsh *et al.* 1984); Community 7 (Benson 1994); Group 10 (Helman *et al.* 1988); Community 14 [*Subalpine valley grassland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.31), *Taraxacum officinale* (0.58), *Trifolium repens* (0.35).

Threats: Some sites in NSW (Kiandra area) and Victoria (near Mt. Wombargo) are subject to excavation by feral pigs, causing these sites to dry. Its greater fertility than surrounding vegetation and permanent wetness makes the community especially vulnerable to weed invasion. *Holcus lanatus*, *Anthoxanthum odoratum* and *Leucanthemum vulgare* have formed extensive colonies at some sites and pose a great threat to this vegetation.

Reservation status: Well reserved, with almost all examples in NSW occurring within Kosciuszko NP.

Extent of clearing: Nil, but this community was probably degraded through decades of grazing in the 19th and 20th centuries.

References: Benson, J.S. (1994) The native grasslands of the Monaro region: southern tablelands of New South Wales. *Cunninghamia* 3: 609–650; Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); Helman, C.E., Gilmour, P.M., Osborne, W.S. & Green, K. (1988) An ecological survey of the upper Cotter catchment wilderness area, Namadgi National Park, ACT. Unpublished report. Conservation Council of the South-east Region and Canberra, Canberra; McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; Walsh, N.G., Barley, R.H. & Gullan, P.K. (1984) The alpine vegetation of Victoria (excluding the Bogong high plains), volume 1. Environmental studies publication no. 376. Department of Conservation, Forests and Lands: Melbourne.

a22: *Poa fawcettiae – Celmisia costiniana – Craspedia maxgrayi* grassland of the Australian Alps bioregion

Scientific Name: *Poa fawcettiae – Celmisia costiniana – Craspedia maxgrayi – Euphrasia collina* subsp. *diversicolor – Pentachondra pumila*

Number of samples:	25
Richness [mean (±SD)]:	20 (4)
Slope (degrees):	(1) 4–18 (22)
Altitude (m asl):	(1727) 1937–2083 (2182)
Ave. Annual Rainfall (mm):	(2070) 2290–2560 (2667)
Temp. Annual Range (°C):	(19.6) 20–20.6 (21.6)

Vegetation Description: Community a22 is a grassland generally dominated by *Poa fawcettiae*, although *Poa hiemata* and *Pentachondra pumila* may be locally dominant. The main forbs include *Celmisia costiniana* and *Craspedia maxgrayi*. Species diversity is usually high (compared with other communities at similar elevation). Tall shrubs

Plate a14: Community a14 is typically dominated by the tussocks of *Poa costiniana* and is common on drainage flats in the montane and subalpine zones of the Australian Alps. This example is at Rocky Plains on the Snowy Mountain Highway, east of Kiandra.

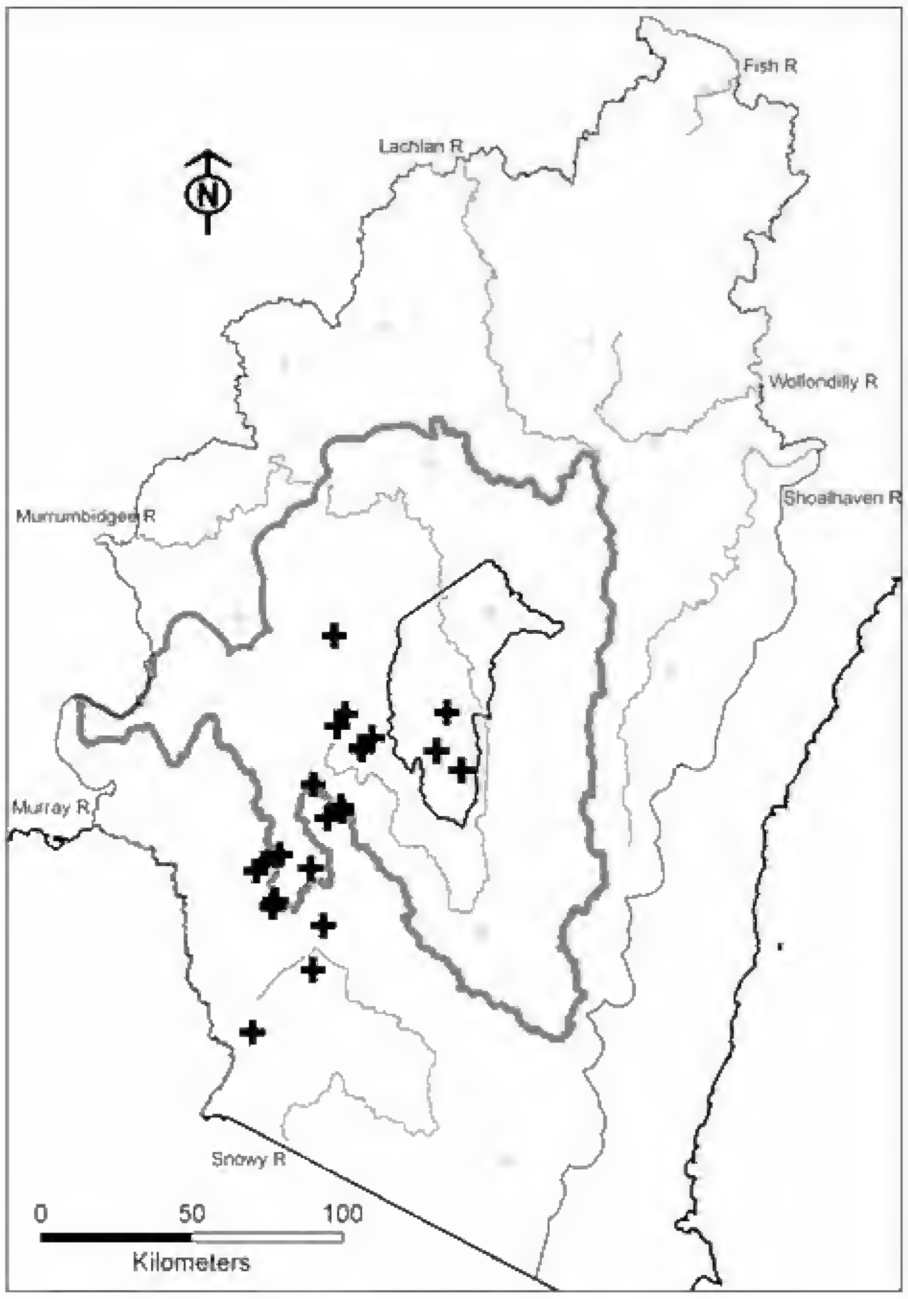

Fig. a14: Distribution of field samples assigned to this community.

are rare. A species-poor variant of the community (Community 18 of McDougall & Walsh 2007) is found on Mt. Jagungal and Mt. Twynam and is incorporated into the current plant community concept. On Mt. Twynam at least, it may be a result of assisted regeneration following severe erosion caused by cattle grazing. That area was the subject of major soil conservation works in the 1960s after grazing was removed.

Community a22 occurs on sites of low relief with deep soils (e.g. saddles and stream heads) between the Main Range and Mt. Jagungal in Kosciuszko NP. It is not known whether this community occurs in the upper Murrumbidgee catchment, being present on the southern and eastern fall of Mt. Jagungal, which marks the boundary of the catchment. Throughout its range, it grades into Community a46 [*Prostanthera cuneata – Orites lancifolius – Nematolepis ovatifolia heathland of the Australian Alps bioregion*]. The ecotone between these communities is large and it will often be difficult to map a boundary between them where the dominants of the heathland are scattered through the grassland.

Characteristic Species:

Species	**C/A**	**Freq**	**C/AO**	**FreqO**	**Fid**
Aciphylla glacialis	1	32	1	<1	P
Acrothamnus montanus	1	48	1	<1	P
Argyrotegium fordianum	1	32	1	<1	P
Australopyrum velutinum	1	20	1	<1	P
Brachyscome scapigera	1	20	1	2	P
Carex breviculmis	1	92	1	12	P
Carex hebes	1	36	1	1	P
Celmisia costiniana	2	76	1	<1	P
Celmisia pugioniformis	1	24	1	2	P
Craspedia aurantia	1	44	1	1	P
Craspedia costiniana	1	28	1	<1	P
Craspedia maxgrayi	1	72	1	<1	P
Deyeuxia crassiuscula	1	20	1	<1	P
Empodisma minus	1	20	2	3	P
Euphrasia collina subsp. *diversicolor*	1	52	1	<1	P
Gentianella muelleriana subsp. *alpestris*	1	40	1	<1	P
Grevillea australis	1	20	2	2	P
Luzula alpestris	1	28	1	<1	P
Luzula modesta	1	20	1	2	P
Lycopodium fastigiatum	1	28	1	<1	P
Microseris lanceolata	1	76	1	6	P
Oreomyrrhis eriopoda	1	76	1	13	P
Pentachondra pumila	1	44	1	<1	P
Pimelea alpina	1	60	1	1	P
Plantago euryphylla	1	24	1	<1	P
Poa costiniana	3	48	2	4	P
Poa fawcettiae	3	60	2	2	P
Prasophyllum spp.	1	36	1	<1	P
Ranunculus graniticola	2	20	1	4	P
Rytidosperma nudiflorum	1	88	1	2	P
Saxipoa saxicola	1	40	1	<1	P
Scleranthus singuliflorus	1	20	1	<1	P
Senecio pinnatifolius var. *alpinus*	1	52	1	3	P
Trisetum spicatum	1	72	1	2	P

Threatened communities: Nil.

Equivalent vegetation types: part of *Celmisia longifolia – Poa caespitosa* alliance (Costin 1954); part of the *Tall alpine herbfield* of Costin *et al.* (2000); combination of Communities 18 [*Poa fawcettiae – Uncinia sulcata grassland*] and 22 [*Poa fawcettiae – Euphrasia collina grassland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.46).

Threats: Chronological aerial photograph interpretation indicates that the area of this community has declined in the past 60 years because of encroachment by shrubs. It is uncertain if this is the result of climate

Plate a22: Community a22 is rare in the study area, found only near the summit of Mt Jagungal. This example is on the slopes of the Main Range of Kosciuszko NP.

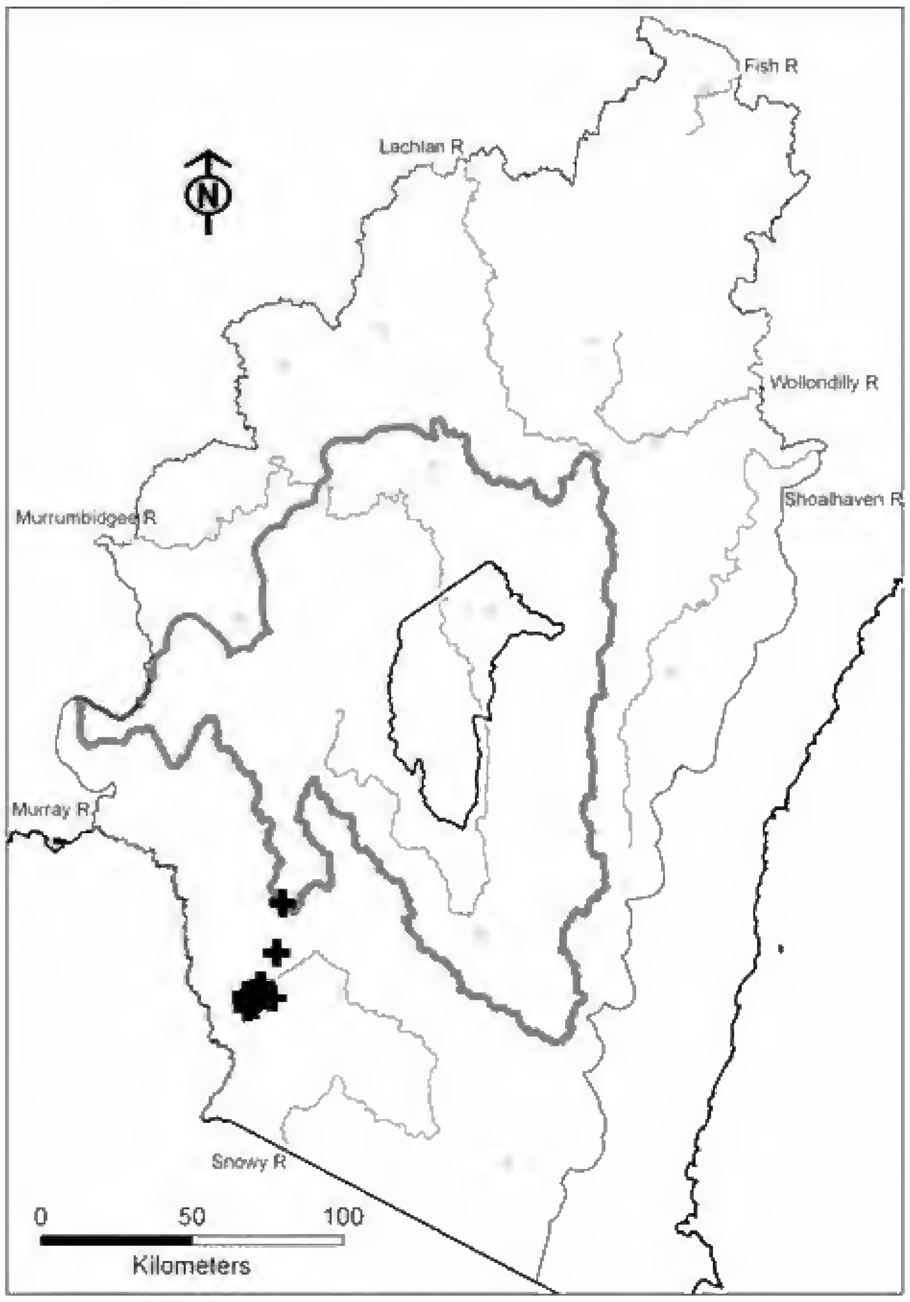

Fig. a22: Distribution of field samples assigned to this community.22

change or disturbance by sheep and cattle, as both factors may favour shrub establishment.

Reservation status: Entirely within Kosciuszko NP.

Extent of clearing: Nil, though formerly much of the community had been severely degraded by sheep and cattle grazing.

References: Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); Costin, A.B., Gray, M., Totterdell, C.J. & Wimbush D.J. (2000) Kosciuszko alpine flora. (CSIRO Publishing: Collingwood); McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

a30: *Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola* grassland of the Australian Alps bioregion

Scientific Name: *Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola – Geranium antrorsum*

Number of samples:	54
Richness [mean (±SD)]:	28 (6)
Slope (degrees):	(0) 2–8 (22)
Altitude (m asl):	(1194) 1285–1397 (1619)
Ave. Annual Rainfall (mm):	(969) 1186–1459 (1814)
Temp. Annual Range (°C):	(21.7) 23.2–24.1 (25)

Vegetation Description: Community a30 is a grassland characterised by a dense cover of one or often several species of *Poa* (mainly *Poa clivicola*, *Poa costiniana*, *Poa hiemata* or *Poa hookeri* but occasionally *Poa petrophila* or *Poa phillipsiana*) with numerous intertussock spaces containing a large range of herbaceous species. Tall shrubs such as *Hakea microcarpa* and *Cassinia monticola* may be present in this community and at times are abundant enough for the vegetation to be structurally an open heathland. Despite the greater shrub cover, such examples are floristically inseparable from surrounding grasslands. There is photographic evidence that these shrubs are recent invaders of the grassland community. Their invasion has probably been facilitated by past grazing disturbance, although climate change will also favour expansion of shrubs into frost hollows.

The component of this community dominated by *Poa hookeri* was regarded as a distinct community by McDougall & Walsh (2007) and may well be so. In the places where it occurs (Kosciuszko NP north from the Happy Jacks area), it forms a mosaic with grassland dominated by other species, making it hard to collect homogeneous samples and increasing the likelihood of combination in the classification. In any case, the grasslands would be inseparable as a mapping unit. The *Poa hookeri*-dominated variant is characterised by dwarf tussocks of *Poa hookeri* and the closed cover of mat-forming herbs, shrubs and low shrubs (e.g. *Calotis pubescens*, *Coprosma nivalis*, *Dillwynia prostrata*, *Pimelea biflora*, *Pultenaea fasciculata*, *Pultenaea polifolia*, *Rutidosis leiolepis*).

Community a30 is the most common grassland of the treeless plains in Kosciuszko NP, occurring from the upper Thredbo Valley in the south to Emu Plain in the west, Cooleman Plain in the north and Snowy Plain in the east. It is the dominant community of large plains such as Kiandra, Happy Jacks and Long Plains and also occurs in the ACT at Cheyenne Flat and Bimberi (and probably elsewhere at high altitude). Its distribution is controlled by temperature and soil depth: low temperatures associated with cold air drainage in the growing season do not favour tall shrub and tree establishment. It is best expressed where soils are deep and on shallow soils it is replaced by heathlands and woodlands.

The lower edge of this community commonly adjoins Community a14 [*Poa costiniana – Carex gaudichaudiana subalpine valley grassland of the Australian Alps bioregion*] and its upper edge is usually Community u158 [*Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion*]. Patches of Community a33 [*Bossiaea foliosa – Cassinia monticola – Kunzea muelleri – Hovea montana heathland of the Australian Alps bioregion*] and Community a34 [*Weeping Snow Gum – Small-fruited Hakea – Blue Snow-grass grassy open woodland of the Australian Alps bioregion*] may be found in a mosaic within the grassland.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acaena echinata	1	33	1	9	P
Aciphylla simplicifolia	1	33	1	2	P
Acrothamnus hookeri	1	65	1	7	P
Ajuga australis	1	26	1	8	P
Asperula gunnii	1	63	1	4	P
Asterolasia trymalioides	1	15	2	<1	P
Australopyrum velutinum	1	28	1	<1	P
Brachyscome aculeata	1	33	1	2	P
Brachyscome decipiens	1	37	1	1	P
Brachyscome scapigera	1	24	1	2	P
Cardamine lilacina	1	22	1	1	P
Carex breviculmis	1	94	1	12	P
Carex hebes	1	28	1	1	P
Celmisia pugioniformis	1	30	1	2	P
Craspedia coolaminica	1	78	1	<1	P
Craspedia jamesii	1	54	1	3	P
Diuris monticola	1	26	1	<1	P
Epilobium billardierianum	1	43	1	1	P
Erigeron bellidioides	1	28	1	<1	P
Euphrasia collina subsp. *paludosa*	1	39	1	2	P
Festuca asperula	1	15	1	1	P
Geranium antrorsum	1	91	1	2	P
Grevillea australis	2	15	1	2	P
Hakea microcarpa	2	19	1	3	P
Hovea montana	1	17	1	1	P
Hovea aff. *heterophylla* (Kiandra)	1	20	1	<1	P
Leptorhynchos elongatus	1	17	1	<1	P
Leptorhynchos squamatus	1	72	1	2	P
Linum marginale	1	13	1	1	P
Luzula flaccida	1	59	1	12	P
Melicytus sp. 'Snowfields'	1	19	1	3	P
Microseris lanceolata	1	56	1	6	P
Oreomyrrhis argentea	1	56	1	<1	P
Pimelea biflora	1	24	1	<1	P
Pimelea linifolia subsp. *caesia*	1	57	1	8	P
Plantago antarctica	1	19	1	<1	P
Plantago euryphylla	1	30	1	<1	P
Poa clivicola	3	50	2	1	P
Poa hiemata	3	24	2	1	P
Poa hookeri	3	43	3	<1	P
Poa costiniana	3	22	2	4	P
Poa fawcettiae	1	17	3	2	P
Poa petrophila	2	17	2	<1	P
Poa phillipsiana	2	41	3	2	P
Podolepis jaceoides	1	46	1	<1	P
Poranthera oreophila	1	54	1	27	P
Prasophyllum spp.	1	15	1	<1	P
Pultenaea fasciculata	2	19	1	<1	P
Pultenaea polifolia	1	20	1	<1	P
Ranunculus graniticola	1	89	1	3	P
Rhodanthe anthemoides	1	37	1	<1	P
Rhytidosporum alpinum	1	19	1	<1	P
Rytidosperma spp.	1	33	1	7	P
Rutidosis leiolepis	2	15	2	<1	P
Scleranthus biflorus	1	81	1	9	P
Scleranthus fasciculatus	1	26	1	<1	P
Senecio pinnatifolius var. *alpinus*	1	50	1	2	P
Swainsona monticola	1	13	1	<1	P
Trisetum spicatum	1	46	1	2	P
Xerochrysum subundulatum	1	26	1	<1	P

Threatened communities: Nil.

Equivalent vegetation types: Vegetation Type 2 (Helman & Gilmour 1985); Group 16 (Helman *et al.* 1988); Community 6 (Benson 1994); combination of Communities 30 [*Poa hiemata – Poa clivicola grassland*] and 31 [*Poa hookeri grassland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.59), *Hypochaeris radicata* (0.59).

Threats: Despite its great spatial extent in conservation reserves, this community is one of the most threatened communities in the Alps and upper Murrumbidgee catchment. Patches of up to 100 m^2 may be overturned by pigs causing the exposure of bare soil, a large reduction in the cover of *Poa* species, and an increase in disturbance tolerant species such as *Geranium antrorsum*, *Drabastrum alpestre* and *Stellaria multiflora* (McDougall & Walsh 2002). Horses are commonly seen in this grassland and presumably selectively graze some of its species. Grassland forbs were found to be selectively grazed by cattle on the Bogong High Plains in Victoria (Van Rees & Holmes 1986), so it is possible that horses are having a significant effect on species abundance and turnover. Investigation of horse diet is urgently required, given the high incidence of rare and threatened plant species in this community (McDougall & Walsh 2007). Invasion by *Leucanthemum vulgare* is also a significant threat, with this weed spreading rapidly in recent years near Tantangara Dam. Based on its invasion ecology and impact elsewhere (Clements *et al.* 2004), the containment of this weed will be essential for the future survival of this community.

Reservation status: Mostly within Kosciuszko NP; some examples on freehold land at Snowy Plain (in the Southern Rivers CMA).

Extent of clearing: Nil, but probably highly degraded in places by domestic grazing and, at Kiandra, mining.

References: Benson, J.S. (1994) The native grasslands of the Monaro region: southern tablelands of New South Wales. *Cunninghamia* 3: 609–650; Helman, C.E. & Gilmour, P.M. (1985) Treeless vegetation above 1,000 metres altitude in the A.C.T. Unpublished report. Conservation Council of the Southeast Region and Canberra: Canberra; Helman, C.E., Gilmour, P.M., Osborne, W.S. & Green, K. (1988) An ecological survey of the upper Cotter catchment wilderness area, Namadgi National Park, ACT. Unpublished report. Conservation Council of the South-east Region and Canberra, Canberra; McDougall, K.L. & Walsh, N.G. (2002) The flora of Nungar plain, a treeless sub-alpine frost hollow in Kosciuszko National Park. *Cunninghamia* 7: 601–610; McDougall, K.L. & Walsh, N.G (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; Van Rees, H. & Holmes, J.H.G. (1986) The botanical composition of the diet of free-ranging cattle on an alpine range in Australia. *Journal of Range Management* 39: 392–395.

Plate a30: The most common grassland of montane to subalpine parts of the Kosciuszko and Namadgi NPs is Community a30, which is dominated by one of several *Poa* species. This example in Nungar Plain (Kosciuszko NP) is dominated by *Poa hookeri*.

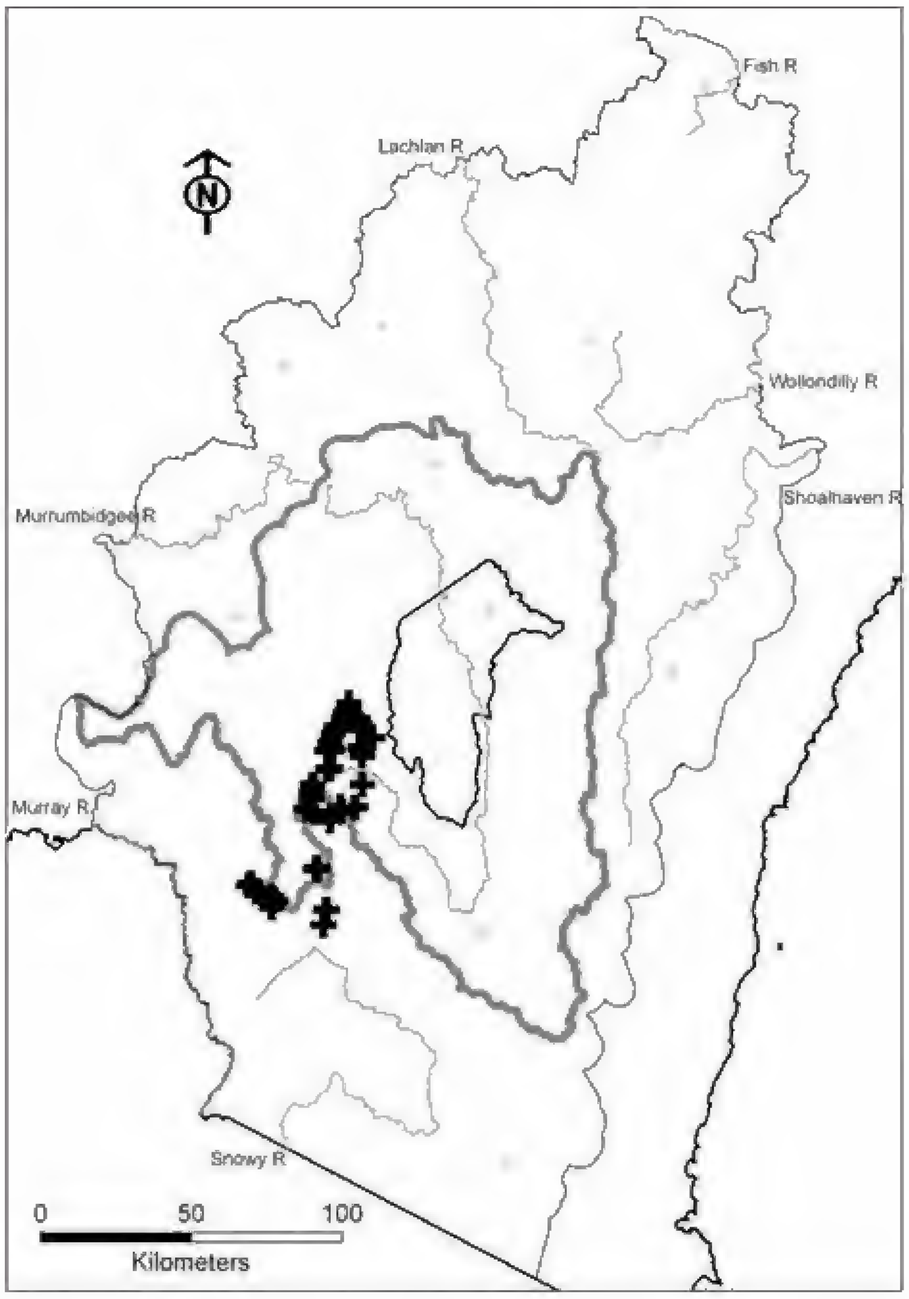

Fig. a30: Distribution of field samples assigned to this community.

a38: *Themeda australis – Galium roddii – Leucochrysum alpinum* grassland of steep limestone slopes in the Australian Alps bioregion

Scientific Name: *Themeda australis – Galium roddii – Leucochrysum alpinum – Cassinia ochracea – Xerochrysum viscosum*

Number of samples:	6
Richness [mean (±SD)]:	15 (4)
Slope (degrees):	(2) 14–27 (39)
Altitude (m asl):	(1185) 1207–1220 (1240)
Ave. Annual Rainfall (mm):	(1080) 1081–1082 (1084)
Temp. Annual Range (°C):	(24.7) 24.7–24.8 (24.8)

Vegetation Description: Community a38 is a grassland mainly dominated by *Themeda australis* and *Poa fawcettiae*, although plant cover is sometimes sparse amongst limestone outcrops. While shrub cover is generally low, there are occasional emergent shrubs of *Cassinia ochracea*, *Grevillea lanigera and Hakea microcarpa*. Several taxa otherwise uncommon in treeless vegetation in the Australian Alps grow in this community which are restricted to limestone landscapes (e.g. *Bulbine glauca, Clematis leptophylla, Convolvulus angustissimus, Galium roddii, Xerochrysum viscosum*).

This community is common on steep slopes in the Blue Waterholes area of Kosciuszko NP (Cave Creek), where it occurs on loose limestone scree and around rocky outcrops. Slopes in similar habitat at Yarrangobilly Caves about 25 km south of Blue Waterholes support small pockets of this community within a forested landscape.

Characteristic Species:

Species	C/A	Freq	C/AO	FreqO	Fid
Brachyscome rigidula	1	33	1	2	P
Carex breviculmis	1	100	1	13	P
Cassinia ochracea	1	67	1	<1	P
Clematis leptophylla	1	33	1	2	P
Convolvulus angustissimus	1	67	1	3	P
Craspedia coolaminica	1	50	1	2	P
Galium roddii	1	50	1	<1	P
Grevillea lanigera	1	33	1	3	P
Hakea microcarpa	1	83	1	3	P
Leucochrysum alpinum	1	100	1	<1	P
Linum marginale	1	67	1	1	P
Muehlenbeckia axillaris	2	33	1	<1	P
Picris angustifolia subsp. *merxmuelleri*	1	67	1	2	P
Pimelea linifolia subsp. *caesia*	1	83	1	8	P
Poa fawcettiae	3	100	3	2	P
Rhodanthe anthemoides	1	33	1	1	P
Themeda australis	3	100	2	21	P
Vittadinia cuneata	1	67	1	2	P
Xerochrysum viscosum	1	83	1	1	P

Threatened communities: Nil.

Equivalent vegetation types: Community 38 [*Themeda triandra – Leucochrysum albicans grassland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Cerastium vulgare* (0.33), *Crepis capillaris* (0.50), *Echium vulgare* (0.33), *Hypochaeris radicata* (0.67), *Rosa rubiginosa* (0.67), *Sedum acre* (0.67), *Tragopogon dubius* (0.67), *Trifolium dubium* (0.83).

Threats: The Cave Creek area has a high diversity of weeds, some of which are locally abundant. *Sedum acre* occupies a niche on rocky sites also occupied by the very restricted *Galium roddii*, which appears to be threatened as a result. Many of the weeds present in Cave Creek are locally dominant in similar habitat at Yarrangobilly Caves (e.g. *Potentilla recta*, *Rosa rubiginosa*, *Tragopogon dubius*, *Verbascum thapsus*). Control of these and other weed species may be required in the future. Control will be difficult, however, because the steep slopes of Cave Creek are unstable and frequent pedestrian traffic could have a significant impact on plants growing there.

Reservation status: Entirely within Kosciuszko NP.

Extent of clearing: Nil.

Reference: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

Plate a38: Community a38 is a grassland with scattered shrubs confined to karst areas at Yarrangobilly and Blue Waterholes in Kosciuszko NP. This photo was taken near Blue Waterholes one year after the 2003 fires which burnt all of the community.

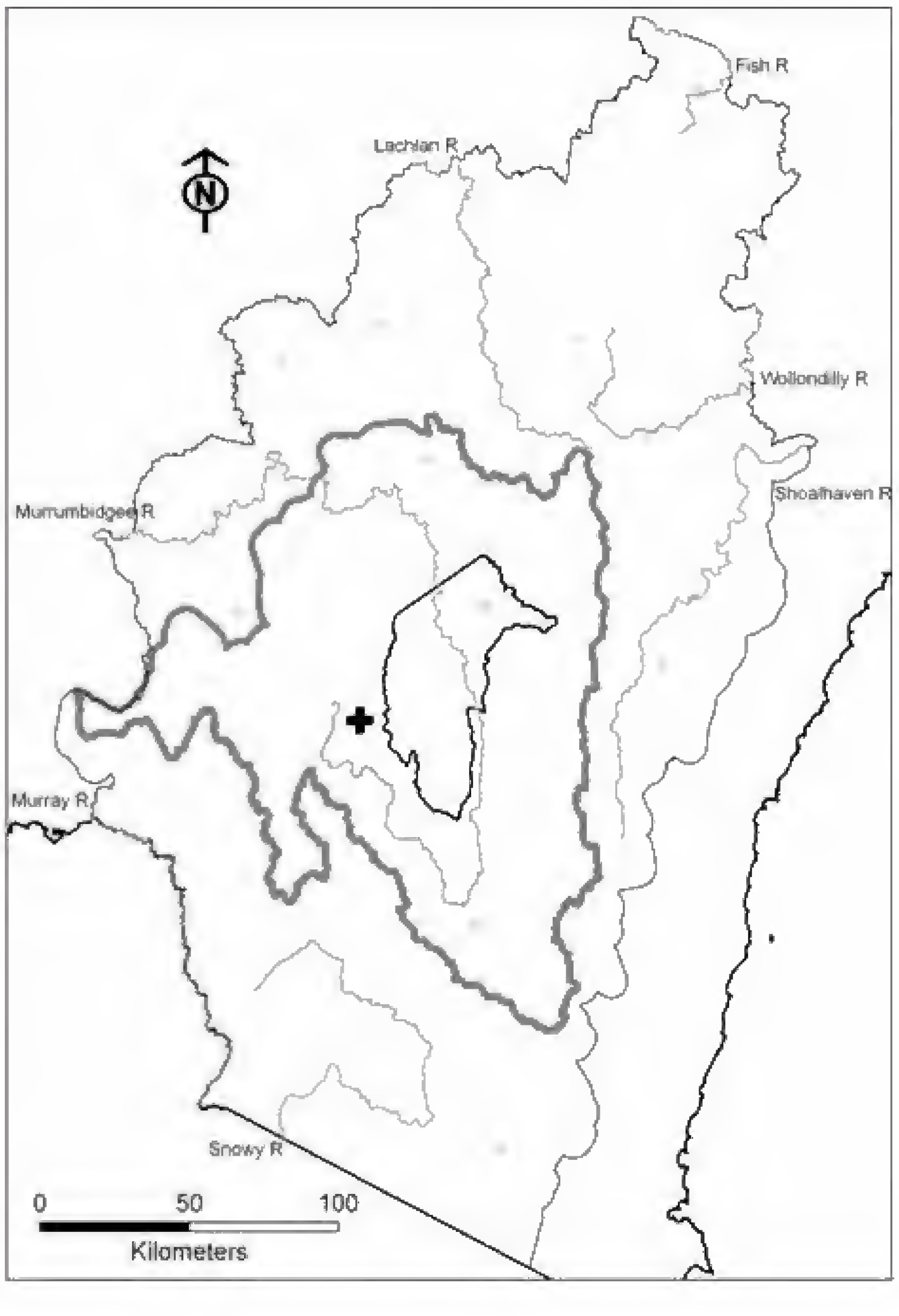

Fig. a38: Distribution of field samples assigned to this community.

Class: Alpine Heaths

a33: *Bossiaea foliosa – Cassinia monticola – Kunzea muelleri – Hovea montana* heathland of the Australian Alps bioregion

Scientific Name: *Bossiaea foliosa – Cassinia monticola – Epacris petrophila – Hovea montana – Kunzea muelleri – Pimelea biflora / Poa hiemata*

Number of samples:	36
Richness [mean (±SD)]:	26 (5)
Slope (degrees):	(0) 3–10 (21)
Altitude (m asl):	(1241) 1330–1582 (1790)
Ave. Annual Rainfall (mm):	(1144) 1506–1777 (2050)
Temp. Annual Range (°C):	(21.1) 21.8–23.3 (24.1)

Vegetation Description: Community a33 can occur as either a closed or open heathland dominated by shrubs 1 to 1.5 metres tall, such as *Bossiaea foliosa*, *Epacris petrophila*, *Hovea montana*, *Cassinia monticola*, *Grevillea australis*, *Kunzea muelleri* or *Podolobium alpestre*. Gaps between shrubs are commonly dominated by *Poa clivicola*, *Poa fawcettiae* or *Poa phillipsiana*, and occasionally *Austrostipa nivicola*, with many forbs characteristic of the adjoining grassland Community a30 [*Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion*]. In the Murray catchment (e.g. upper Tooma River catchment), the heathland is commonly dominated by *Bossiaea foliosa* and despite the closed nature of this variant, the diversity of forbs and grasses is high. *Dichelachne crinita*, an uncommon species in the higher Alps, is a common component there.

Within the upper Murrumbidgee catchment, this community is abundant in Kosciuszko NP (e.g. Long Plain, Bullocks Hill, Currango Plain) and Namadgi NP (e.g. Mt. Bimberi, Mt. Murray, Mt. Gingera). It may be found in a mosaic with Community a30 [*Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion*] but usually occupies the upper slopes of subalpine frost hollows.

Community a33 is a combination of three heathland Communities 33, 35 and 36 of McDougall & Walsh (2007). These communities may be separable floristically, each being influenced by the herbaceous composition of surrounding grassland communities. However, at their extremities the differences between them are minor and, for mapping purposes, they are likely to be indistinguishable.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Aciphylla simplicifolia	1	72	1	2	P
Acrothamnus hookeri	1	33	1	8	P
Asperula gunnii	1	58	1	4	P
Bossiaea foliosa	2	31	2	4	P
Brachyscome decipiens	1	25	1	1	P
Brachyscome scapigera	1	25	1	2	P
Brachyscome spathulata	1	33	1	11	P
Cardamine lilacina	1	39	1	<1	P
Carex breviculmis	1	92	1	12	P
Carex hebes	1	22	1	1	P
Cassinia monticola	1	56	1	<1	P
Celmisia pugioniformis	1	42	1	2	P
Craspedia coolaminica	1	28	1	2	P
Craspedia jamesii	1	75	1	3	P
Empodisma minus	1	25	2	3	P
Epacris gunnii	1	33	1	2	P

Plate a33: Community a33 is a common shrubland found in and around Kosciuszko and Namadgi NPs. The dominant may be one or more of several shrub species (*Bossiaea foliosa* in this photo taken in Long Plain (Kosciuszko NP), and the understorey is typically composed of grasses and forbs found in neighbouring grassland communities.

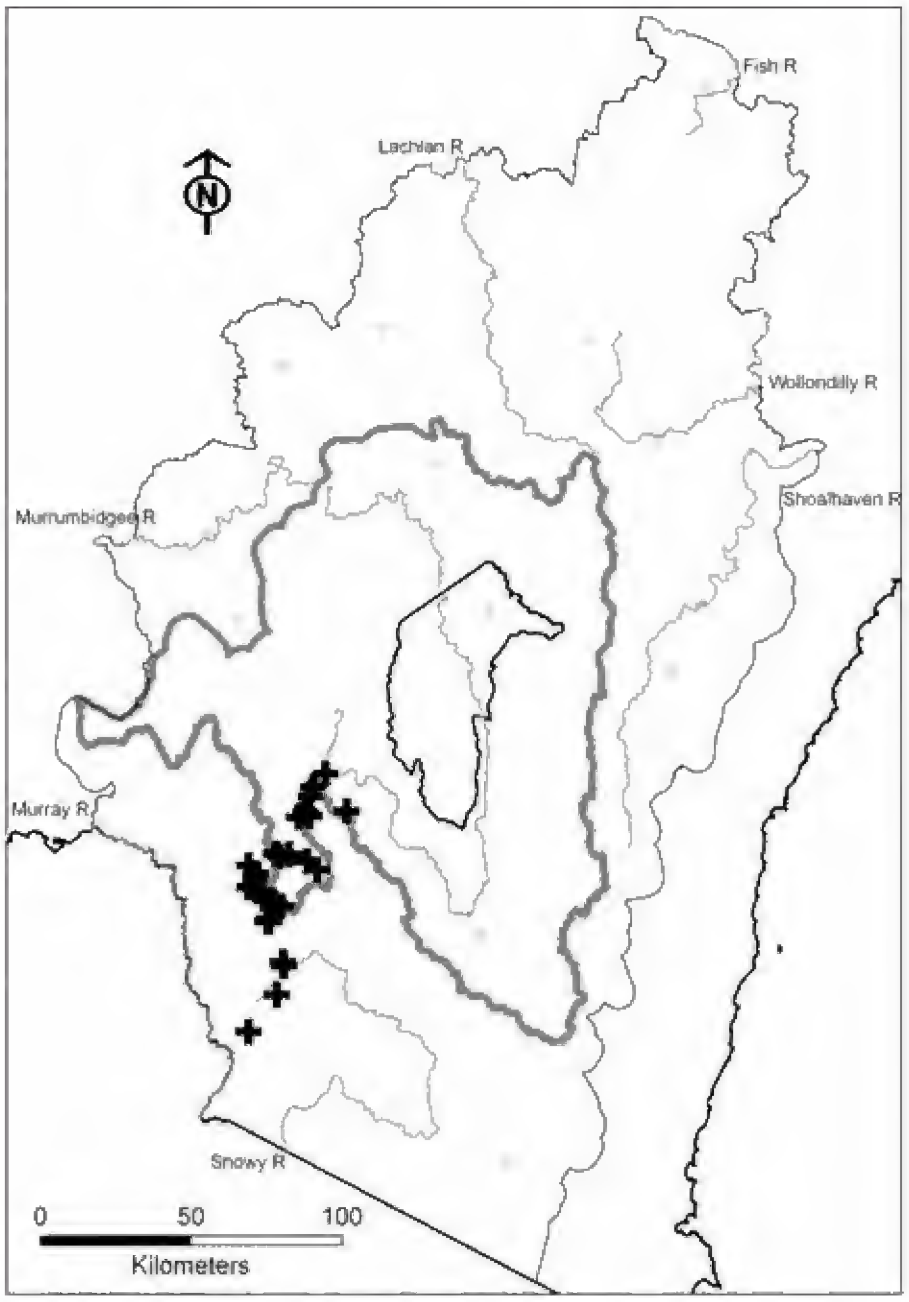

Fig. a33: Distribution of field samples assigned to this community.

Erigeron bellidioides	1	39	1	<1	P
Euphrasia collina subsp. *paludosa*	1	31	1	2	P
Geranium antrorsum	1	33	1	3	P
Grevillea australis	1	50	2	1	P
Hakea microcarpa	1	33	1	3	P
Hovea montana	2	50	1	<1	P
Kunzea muelleri	2	47	2	<1	P
Leptorhynchos squamatus	1	61	1	2	P
Luzula modesta	1	31	1	2	P
Microseris lanceolata	1	69	1	6	P
Oreomyrrhis argentea	1	33	1	<1	P
Pimelea biflora	1	36	1	<1	P
Pimelea linifolia subsp. *ceasia*	1	33	1	8	P
Poa clivicola	3	28	3	2	P
Poa costiniana	2	53	2	4	P
Poa hiemata	1	53	3	1	P
Poranthera oreophila	1	50	1	27	P
Ranunculus graniticola	1	83	1	3	P
Scleranthus biflorus	1	64	1	9	P
Senecio pinnatifolius var. *alpinus*	1	44	1	3	P
Trisetum spicatum	1	31	1	2	P
Xerochrysum subundulatum	1	47	1	<1	P

Threatened communities: Nil.

Equivalent vegetation types: Combination of Communities 33 [*Northern Alps Hovea montana open heathland*], 35 [*Bossiaea foliosa – Epacris petrophila heathland*] and 36 [*Broadway Bossiaea foliosa closed heathland*] (McDougall & Walsh 2007); not clearly identified in other previous vegetation descriptions.

Frequently occurring weeds: *Acetosella vulgaris* (0.58), *Hypochaeris radicata* (0.36).

Threats: This community is frequently used by feral horses. Although trampling and selective grazing undoubtedly occur, the overall effect is likely to be minimal, because most shrubs in this community are unpalatable and facultative resprouters; in addition, most palatable species will be found in adjoining grassland. The greatest threat appears to be invasion by *Leucanthemum vulgare*. In an example of several hectares near Tantangara Dam, this weed has a cover of about 80%.

Reservation status: Mostly in conservation reserves (Kosciuszko NP, Bimberi NR, Namadgi NP), with small amounts on freehold land at Snowy Plain in the Southern Rivers CMA.

Extent of clearing: Probably negligible and this community appears to be expanding into grassland either because of past land use disturbance or climate change (or both).

Reference: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

a39: *Epacris* sp. – *Pentachondra pumila – Poa fawcettiae* heathland of the Australian Alps bioregion

Scientific Name: *Epacris* sp. – *Pentachondra pumila – Poa fawcettiae – Senecio pectinatus – Craspedia maxgrayi*

Number of samples: 10
Richness [mean (±SD)]: 19 (4)
Slope (degrees): (2) 6–10 (17)
Altitude (m asl): (1729) 1936–2117 (2147)
Ave. Annual Rainfall (mm): (2095) 2327–2581 (2634)
Temp. Annual Range (°C): (19.7) 19.9–20.6 (21.6)

Vegetation Description: Community a39 is a low heathland dominated by an undescribed *Epacris* species (Costin *et al.* 2000), *Kunzea muelleri* or occasionally *Epacris petrophila*. It occurs on the upper granite or phyllite slopes and summits of the Kosciuszko Main Range, with an outlier on the summit of Mt. Jagungal. Sites containing this community are generally rocky with shallow soil. An unusual feature of some stands is the presence of *Baeckea gunniana*, a species usually associated with moist sites. This species can sometimes be found layering over large granite boulders. The diversity and abundance of herb species is usually low. Rock and bare ground are common. This heathland has some floristic elements of Community 40 of McDougall & Walsh (2007; *Epacris gunnii – Chionohebe pulvinatus* feldmark; e.g. *Leucochrysum alpinum* and *Luzula australasica*), but is far more diverse and lacking in low–growing species endemic to that community (*Colobanthus pulvinatus, Ranunculus acrophilus, Chionohebe densifolia, Euphrasia collina* subsp. *lapidosa, Kelleria dieffenbachii*).

On less exposed sites with deeper soil profiles, Community a39 often grades into Community a46 [*Prostanthera cuneata – Orites lancifolius – Nematolepis ovatifolia heathland of the Australian Alps bioregion*]. Community a39 is found in Murray and Southern Rivers catchments but may extend into the upper Murrumbidgee catchment area.

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Aciphylla glacialis	1	30	1	<1	P
Acrothamnus montanus	2	50	1	1	P
Brachyscome tenuiscapa	1	20	1	<1	P
Carex breviculmis	1	100	1	13	P
Carex hebes	1	30	1	1	P
Celmisia costiniana	1	80	1	1	P
Craspedia aurantia	1	60	1	1	P
Craspedia costiniana	1	40	1	<1	P
Craspedia maxgrayi	1	70	1	<1	P
Deyeuxia carinata	1	20	1	<1	P
Deyeuxia crassiuscula	1	30	1	<1	P
Empodisma minus	1	30	2	3	P
Epacris sp. (*sensu* Costin *et al.* 2000)	3	90	1	2	P
Erigeron bellidioides	1	30	1	1	P
Erigeron nitidus	1	30	1	<1	P
Euphrasia collina subsp. *diversicolor*	1	40	1	1	P
Gentianella muelleriana subsp. *alpestris*	1	30	1	<1	P
Grevillea australis	2	40	1	2	P
Kunzea muelleri	5	30	2	1	P
Luzula alpestris	1	40	1	<1	P
Microseris lanceolata	1	60	1	7	P
Oreomyrrhis eriopoda	1	80	1	13	P
Pentachondra pumila	1	70	1	<1	P
Pimelea alpina	1	50	1	1	P
Poa costiniana	2	40	2	5	P
Poa fawcettiae	2	50	3	2	P
Poa hiemata	3	20	2	2	P
Prasophyllum spp.	1	20	1	<1	P
Rytidosperma nudiflorum	1	60	1	2	P
Saxipoa saxicola	1	20	1	<1	P
Senecio pectinatus var. *major*	1	40	1	<1	P
Senecio pinnatifolius var. *alpinus*	1	30	1	3	P
Stackhousia pulvinaris	1	20	1	<1	P
Trisetum spicatum	1	40	1	3	P

Threatened communities: Nil.

Equivalent vegetation types: *Epacris serpyllifolia – Kunzea muelleri* alliance (Costin 1954); a combination of the *Epacris microphylla* and *Kunzea muelleri* associations (McVean 1969); Community 39 [*Kosciuszko alpine Epacris – Kunzea open heathland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.30).

Threats: Some examples (e.g. summit of Mt. Kosciuszko) are subject to trampling pressure by tourists. The top stations of some lifts in NSW ski resorts are positioned within this community. The impact of these pressures on the overall community is currently low.

Plate a39: Community a39 is a low shrubland occurring on exposed sites in the Australian Alps, with a species-poor herbaceous component. This example is on the slopes of Mt Perisher, Kosciuszko NP.

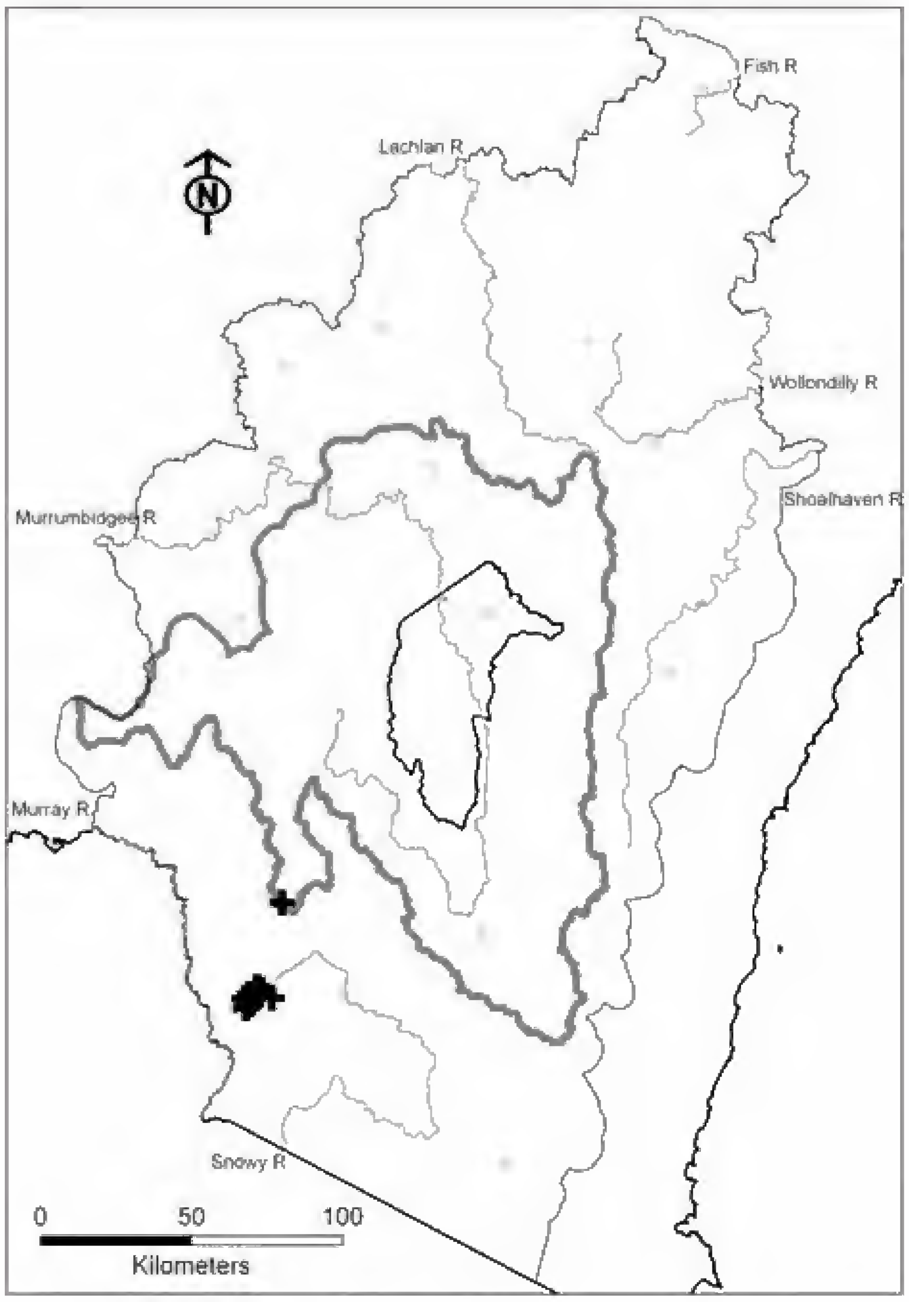

Fig. a39: Distribution of field samples assigned to this community.

Reservation status: Entirely within Kosciuszko NP.

Extent of clearing: Nil, but severely degraded by grazing prior to the 1950s.

References: Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; McVean, D.N. (1969) Alpine vegetation of the central Snowy Mountains of New South Wales. *Journal of Ecology* 57: 67–86.

a42: *Epacris celata – Poa clivicola – Dillwynia palustris* grassy heathland of the Australian Alps bioregion

Scientific Name: *Epacris celata – Epacris gunnii / Poa clivicola – Deyeuxia gunniana – Cotula alpina – Lomandra* **aff.** *micrantha***.**

Number of samples:	3
Richness [mean (±SD)]:	26 (4)
Slope (degrees):	(0) 0–2 (3)
Altitude (m asl):	(1153) 1153–1155 (1156)
Ave. Annual Rainfall (mm):	(1367) 1369–1372 (1373)
Temp. Annual Range (°C):	(24.1) 24.2–24.2 (24.2)

Vegetation Description: Community a42 is a grassy heathland comprising very short plants of *Epacris celata* and *Epacris gunnii*. In stature and abundance, the shrubs are less prominent than the grasses (*Poa clivicola*, *Poa sieberiana* and *Themeda australis*), which makes the community appear more like a grassland than an open heathland. This community is not closely related to any of the other communities in the upper Murrumbidgee catchment. It is considered rare and isolated from other treeless vegetation in the Australian Alps bioregion.

This community is currently recorded only from McPhersons Plain, part of a high plateau on the western side of the Tumut Valley to the west of Kosciuszko NP. Considering that other treeless plains on the plateau nearby (Sparks Plain and Tomneys Plain) have not been surveyed, it is likely that it is not restricted to McPhersons Plain.

Adjoining communities include Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*] on upper slopes, Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*] in areas of impeded drainage, and Community a14 [*Poa costiniana – Carex gaudichaudiana subalpine valley grassland of the Australian Alps bioregion*], as well as Community a9 [*Carex gaudichaudiana – Ranunculus amphitrichus – Phragmites australis aquatic herbfield of waterways in the Australian Alps and South Eastern Highlands bioregions*] along waterways. Examples of Community a6 [*Ranunculus millanii – Lobelia surrepens – Carex gaudichaudiana herbfield of shallow depressions in the Australian Alps bioregion*] are scattered within the community.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Asperula gunnii	1	67	1	5	P
Baloskion australe	1	33	1	2	P
Brachyscome decipiens	1	67	1	2	P
Brachyscome scapigera	1	100	1	2	P
Bulbine bulbosa	1	67	1	4	P
Caesia alpina	1	33	1	<1	P
Carex hebes	1	33	1	2	P
Cotula alpina	1	100	1	1	P

Deyeuxia crassiuscula	1	33	1	<1	P
Deyeuxia gunniana	1	100	1	<1	P
Dillwynia palustris	2	33	1	<1	P
Diuris monticola	1	33	1	<1	P
Diuris spp.	1	33	1	<1	P
Empodisma minus	1	67	2	4	P
Epacris celata	3	100	2	<1	P
Epacris gunnii	3	100	1	2	P
Erigeron bellidioides	1	33	1	1	P
Euphrasia collina subsp. *paludosa*	2	100	1	2	P
Gonocarpus micranthus	1	67	1	2	P
Hakea microcarpa	1	67	1	3	P
Hydrocotyle sibthorpioides	1	67	2	5	P
Hypericum japonicum	1	67	1	4	P
Lomandra aff. *micrantha*	1	67	2	<1	P
Oreobolus distichus	1	33	1	<1	P
Pimelea biflora	1	33	1	<1	P
Plantago euryphylla	1	33	1	1	P
Poa clivicola	5	67	3	2	P
Prasophyllum spp.	1	67	1	<1	P
Pultenaea polifolia	1	33	1	<1	P
Ranunculus graniticola	1	100	1	4	P
Stylidium montanum	2	100	1	25	P
Carex breviculmis	1	67	1	13	C
Luzula flaccida	1	67	1	13	C
Poa sieberiana	3	67	2	48	C
Poranthera oreophila	2	67	1	27	C
Themeda australis	1	67	2	21	C

Threatened communities: Nil.

Equivalent vegetation types: Community 42 [*Epacris celata – Poa clivicola open heathland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Cerastium vulgare* (0.33), *Holcus lanatus* (0.33), *Hypochaeris radicata* (0.67), *Poa pratensis* (0.33), *Trifolium repens* (0.67).

Threats: Some of the community is the subject of a conservation agreement that fosters management of the vegetation for its significant biodiversity features. Despite this, the community is threatened overall by feral animals, stray domestic stock from neighbouring properties and future changes in land use.

Reservation status: Not present in a conservation reserve. McPhersons Plain is partly in a State Forest lease and partly freehold. Treeless plains nearby are freehold.

Extent of clearing: Nil, but probably locally degraded by historic grazing practices.

References: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

a43: *Bossiaea riparia – Themeda australis* low open heathland of the Australian Alps bioregion

Scientific Name: *Bossiaea riparia – Cryptandra amara – Hakea microcarpa – Dillwynia prostrata / Themeda australis*

Number of samples:	3
Richness [mean (±SD)]:	23 (5)
Slope (degrees):	(3) 6–12 (15)
Altitude (m asl):	(1198) 1209–1254 (1289)
Ave. Annual Rainfall (mm):	(968) 971–980 (986)
Temp. Annual Range (°C):	(24.5) 24.7–24.9 (25)

Vegetation Description: Community a43 is an open heathland characterised by an extensive cover of a prostrate form of the shrub *Bossiaea riparia* and much exposed rock. The associated flora is variable and may depend on the amount of soil present and the composition

Plate a42: Community a42 at McPhersons Plain, Kosciuszko NP. It is a grassy heathland which may be dominated by *Epacris* spp. or *Poa* species depending on time since disturbance (e.g. by grazing). It is confined to the plains in and around Bago State Forest, between Talbingo and Tumbarumba.

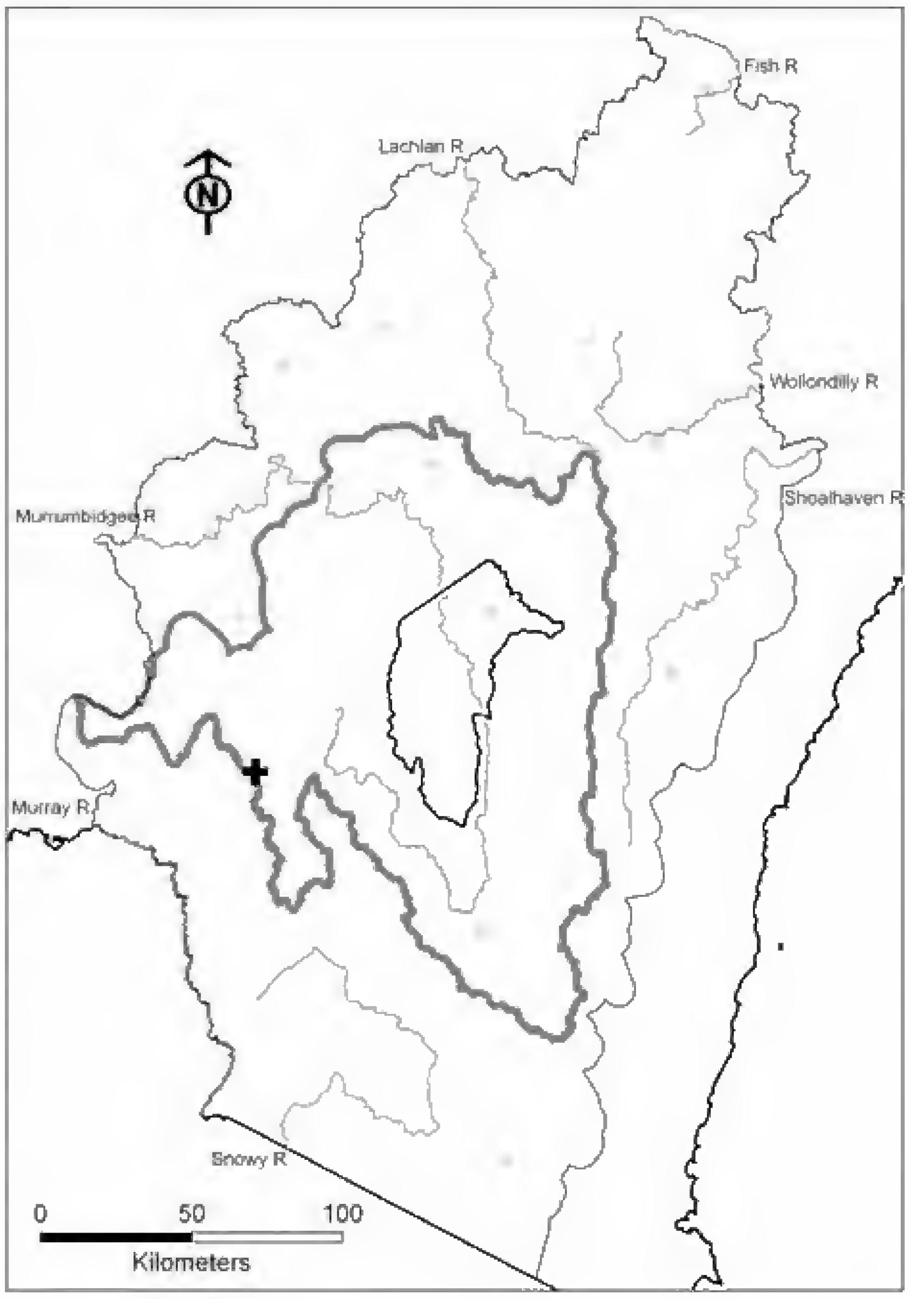

Fig. a42: Distribution of field samples assigned to this community.

of surrounding communities. Despite its variability, the community has few affinities with other communities. Of communities present in treeless subalpine plains, five species were restricted to Community a43 or very rare elsewhere (*Bossiaea riparia*, *Cryptandra amara*, *Daviesia mimosoides* subsp. *acris*, *Mirbelia oxylobioides*, *Patersonia sericea* var. *longifolia*). *Patersonia sericea* var. *longifolia* is otherwise unknown in the Australian Alps bioregion.

This community is endemic to the upper Murrumbidgee catchment, being restricted to the rocky slopes above the upper Murrumbidgee River, and a few of its tributaries (in the vicinity of Currango Plain and Tantangara Dam). It possibly occurs at lower elevations in the Yaouk valley. It is typically found amongst Community a30 [*Poa hookeri – Poa clivicola – Oreomyrrhis argentea – Ranunculus graniticola grassland of the Australian Alps bioregion*] and sometimes in association with Community a34 [*Weeping Snow Gum – Small-fruited Hakea – Blue Snow-grass grassy open woodland of the Australian Alps bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Agrostis venusta	1	33	1	<1	P
Australopyrum velutinum	1	33	1	<1	P
Austrostipa nivicola	1	33	1	<1	P
Bossiaea riparia	2	100	1	<1	P
Calotis glandulosa	2	33	1	<1	P
Carex hebes	1	33	1	2	P
Cassinia monticola	1	33	1	1	P
Craspedia aurantia	1	33	1	2	P
Cryptandra amara	1	67	1	1	P
Dillwynia prostrata	4	67	2	<1	P
Diuris monticola	1	67	1	<1	P
Epilobium billardierianum	1	67	1	2	P
Festuca muelleri	1	33	1	<1	P
Hakea microcarpa	1	100	1	3	P
Luzula novae-cambriae	1	33	1	<1	P
Patersonia sericea var. *longifolia*	2	33	2	1	P
Pimelea linifolia subsp. *caesia*	1	100	1	8	P
Pimelea pauciflora	1	33	1	<1	P
Poa clivicola	2	67	3	2	P
Poa hookeri	3	33	3	<1	P
Podolepis jaceoides	1	67	1	1	P
Pultenaea subspicata	2	33	2	2	P
Rhodanthe anthemoides	1	33	1	1	P
Rutidosis leiolepis	2	33	2	<1	P
Rytidosperma erianthum	1	33	2	1	P
Saxipoa saxicola	1	33	1	<1	P
Senecio pinnatifolius var. *alpinus*	1	67	1	3	P
Themeda australis	1	100	2	21	P
Trisetum spicatum	1	67	1	3	P
Xerochrysum subundulatum	1	33	1	1	P
Carex breviculmis	1	67	1	13	C
Euchiton japonicus	1	67	1	15	C
Luzula flaccida	1	67	1	13	C
Microlaena stipoides	1	67	2	34	C

Threatened communities: Nil.

Equivalent vegetation types: Community 43 [*Bossiaea riparia dwarf heathland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.33), *Agrostis capillaris* (0.33), *Aira caryophyllea* (0.33), *Anthoxanthum odoratum* (0.33), *Hypericum perforatum* (0.33), *Hypochaeris radicata* (1.00), *Vulpia bromoides* (0.33).

Threats: None obvious.

Reservation status: All known examples occur within Kosciuszko NP.

Plate a43: Community a43 (left hand side adjoining a30) is a low shrubland dominated by *Bossiaea riparia* and confined to the upper Murrumbidgee valley in the vicinity of Tantangara Dam (Kosciuszko NP, this photo) and Currango Plain.

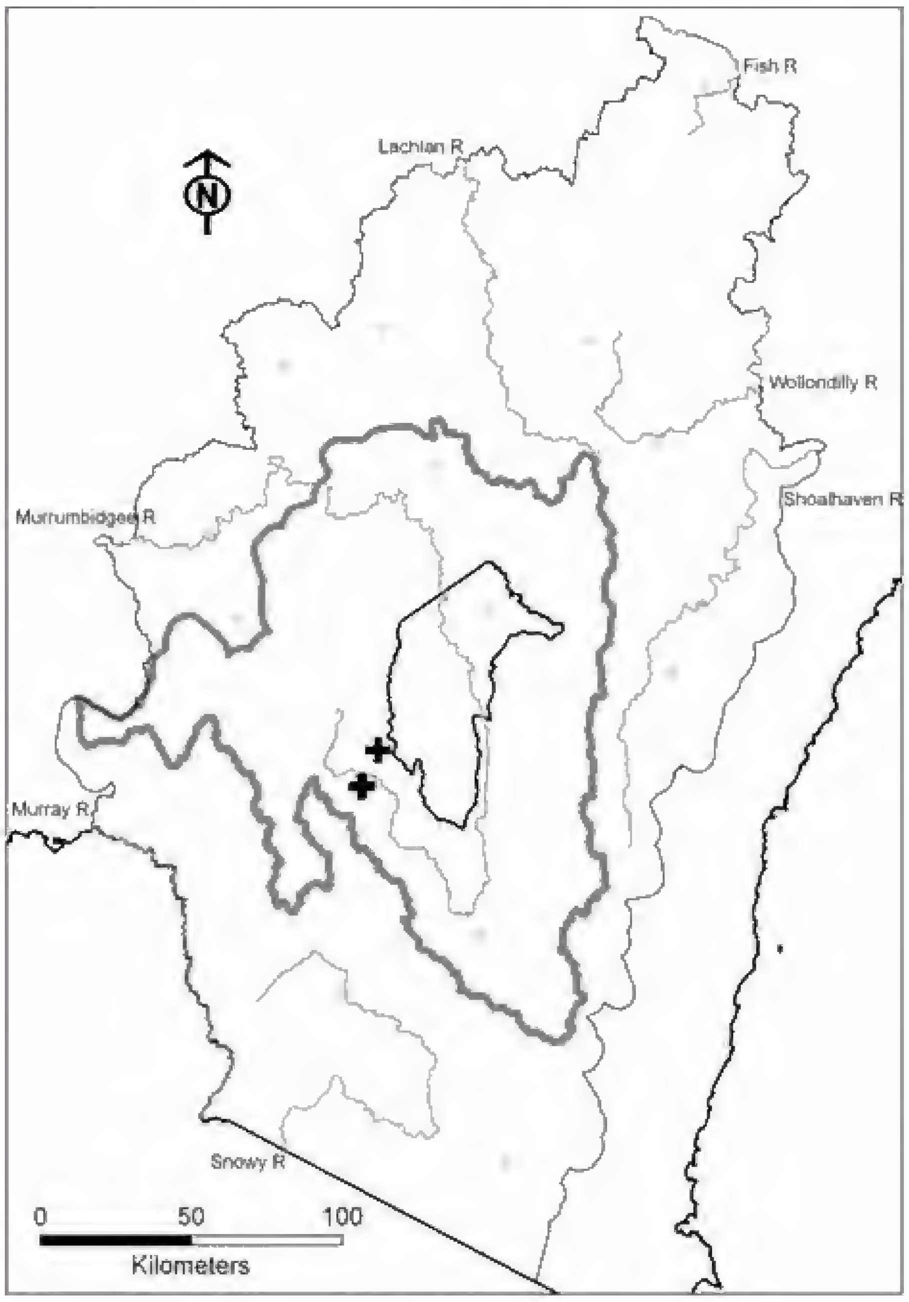

Fig. a43: Distribution of field samples assigned to this community.

Extent of clearing: Unknown but probably nil. Many examples on the steep slopes of the Murrumbidgee River at Gulf Bend are sparsely vegetated and may be recovering from past disturbance associated with domestic grazing.

References: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

a46: *Prostanthera cuneata – Orites lancifolius – Nematolepis ovatifolia* heathland of the Australian Alps bioregion

Scientific Name: *Nematolepis ovatifolia – Orites lancifolius – Prostanthera cuneata – Olearia brevipedunculata – Grevillea australis*

Number of samples:	17
Richness [mean (±SD)]:	22 (7)
Slope (degrees):	(1) 5–12 (18)
Altitude (m asl):	(1635) 1749–1945 (2009)
Ave. Annual Rainfall (mm):	(1851) 2075–2296 (2438)
Temp. Annual Range (°C):	(20.2) 20.6–21.5 (21.7)

Vegetation Description: Community a46 is a shrubland dominated by species such as *Nematolepis ovatifolia*, *Orites lancifolia* and/or *Prostanthera cuneata.* Other shrubs such as *Grevillea australis*, *Hovea montana*, *Kunzea muelleri* and *Oxylobium ellipticum* may be locally abundant. Shrub cover is sparse at its upper altitudinal limits and closed at its lower. Its distribution is scattered and common on the dry slopes of the Kosciuszko Main Range between Dead Horse Gap (near Thredbo) and Mt. Jagungal.

Community a46 is a combination of two shrub-dominated communities described by McDougall & Walsh (2007), representing a continuum from near the treeline, where shrubs are tall and closed with a sparse herb cover, to the alpine zone, where shrubs are shorter and gaps between shrubs are filled with species characteristic of Community a22 [*Poa fawcettiae – Celmisia costiniana – Craspedia maxgrayi grassland of the Australian Alps bioregion*]. At their boundaries, these communities are probably inseparable. At its lower extent, community a46 grades into Community u158 [*Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion*].

There are outliers in the upper Murrumbidgee catchment in the upper Tumut valley and at Kiandra. The Kiandra example contains the northern-most population of *Phebalium squamulosum* subsp. *alpinum*.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Aciphylla simplicifolia	1	24	1	2	P
Acrothamnus montanus	1	29	1	1	P
Argyrotegium fordianum	1	24	1	<1	P
Asperula gunnii	1	41	1	5	P
Carex breviculmis	1	82	1	13	P
Celmisia costiniana	2	24	1	1	P
Celmisia pugioniformis	1	47	1	2	P
Craspedia aurantia	1	65	1	1	P
Deyeuxia crassiuscula	1	24	1	<1	P
Empodisma minus	1	24	2	3	P
Erigeron bellidioides	1	35	1	1	P
Erigeron nitidus	1	59	1	<1	P
Euphrasia collina subsp. *diversicolor*	1	29	1	1	P
Gonocarpus montanus	1	24	1	1	P
Grevillea australis	2	82	1	1	P
Leptorhynchos squamatus	2	24	1	3	P
Luzula alpestris	1	24	1	<1	P
Luzula modesta	1	29	1	2	P

Plate a46: Sheltered sites with shallow soils and exposed rock at high elevation in Kosciuszko NP are typically shrub-dominated with a very sparse understorey of herbs; this example near Mt Blue Cow, Kosciuszko NP.

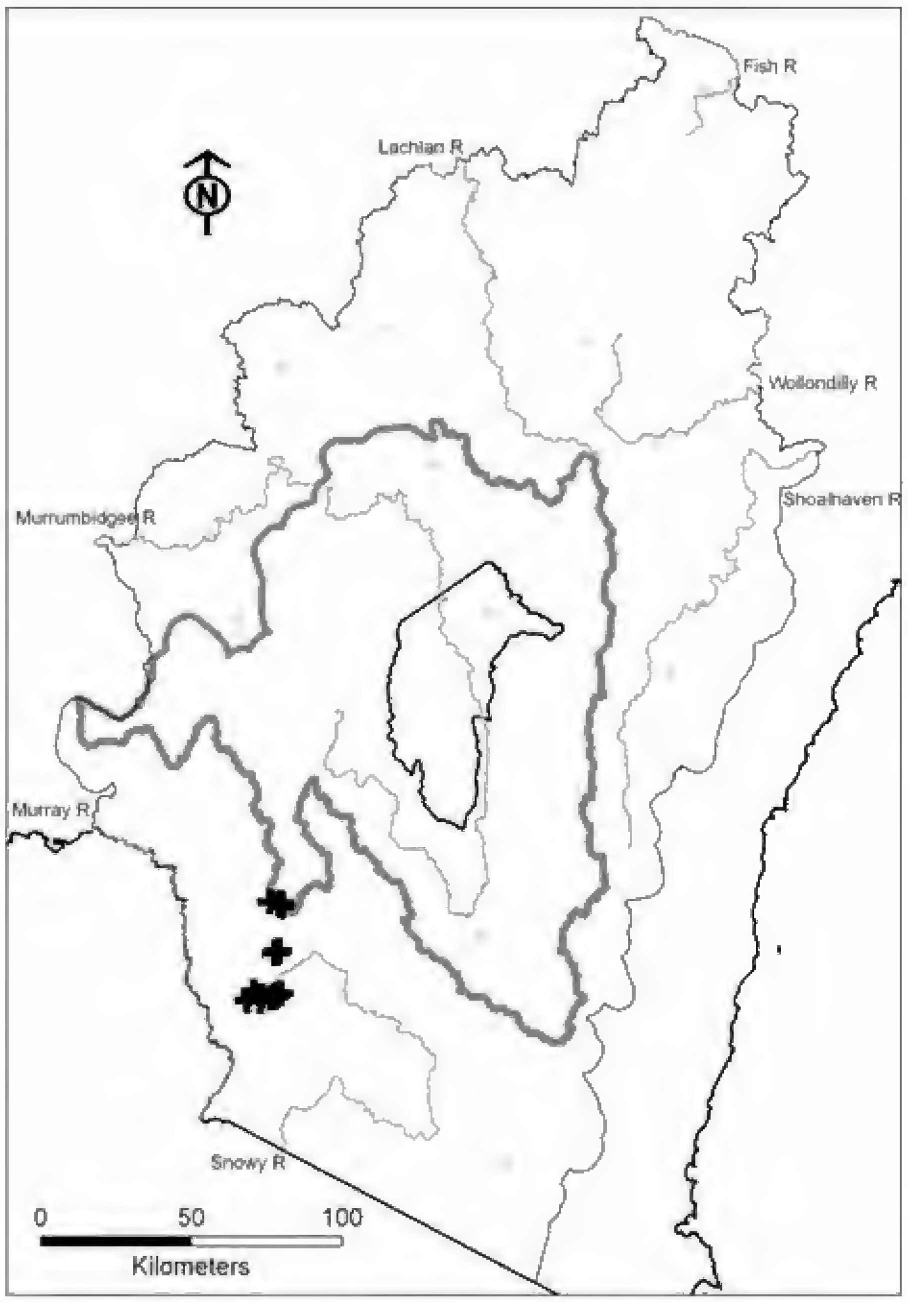

Fig. a46: Distribution of field samples assigned to this community.

Lycopodium fastigiatum	1	29	1	<1	P
Melicytus sp. 'Snowfields'	1	53	1	3	P
Microseris lanceolata	1	47	1	7	P
Nematolepis ovatifolia	3	82	2	<1	P
Olearia algida	1	29	1	<1	P
Olearia brevipedunculata	1	29	1	<1	P
Olearia phlogopappa	1	24	1	3	P
Oreomyrrhis eriopoda	1	65	1	13	P
Orites lancifolius	3	24	2	<1	P
Oxylobium ellipticum	2	29	1	4	P
Pimelea alpina	1	71	1	1	P
Plantago euryphylla	1	41	1	<1	P
Poa costiniana	2	29	2	5	P
Poa fawcettiae	4	35	3	2	P
Poa hiemata	3	65	2	1	P
Prostanthera cuneata	2	53	2	<1	P
Ranunculus graniticola	1	41	1	4	P
Rytidosperma nudiflorum	1	41	1	2	P
Scleranthus biflorus	1	41	1	10	P
Senecio pinnatifolius var. *alpinus*	1	35	1	3	P
Trisetum spicatum	1	41	1	2	P
Viola betonicifolia	1	53	1	27	C

Threatened communities: Nil.

Equivalent vegetation types: part of *Oxylobium ellipticum – Podocarpus alpinus* alliance (Costin 1954); *Phebalium ovatifolium* association (McVean 1969); part of *Heath* formation (Costin *et al.* 2000); combination of communities 23 [*Grevillea australis – Nematolepis ovatifolia open heathland*] and 46 [*Nematolepis ovatifolia – Prostanthera cuneata closed heathland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.65).

Threats: None obvious. This community is apparently expanding either under the influence of climate change or because of past disturbance from grazing. Much of this community was burnt in 2003, but regeneration of most species seems to have occurred (Walsh & McDougall 2005).

Reservation status: All within Kosciuszko NP.

Extent of clearing: Nil.

References: Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); Costin, A.B., Gray, M., Totterdell, C.J. & Wimbush D.J. (2000) Kosciuszko alpine flora. (CSIRO Publishing: Collingwood); McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; McVean, D.N. (1969) Alpine vegetation of the central Snowy Mountains of New South Wales. *Journal of Ecology* 57: 67–86.

a51: *Podocarpus lawrencei – Rytidosperma alpicola – Brachyscome nivalis* low open heathland of rock outcrops of the Australian Alps bioregion

Scientific Name: *Podocarpus lawrencei – Grevillea australis / Rytidosperma alpicola – Brachyscome nivalis – Polystichum proliferum*

Number of samples:	5
Richness [mean (±SD)]:	22 (7)
Slope (degrees):	(9) 15–22 (30)
Altitude (m asl):	(1911) 2029–2076 (2153)
Ave. Annual Rainfall (mm):	(2316) 2322–2576 (2653)
Temp. Annual Range (°C):	(19.7) 20–20.2 (20.7)

Vegetation Description: Community a51 is a low sparse shrubland dominated by *Rytidosperma alpicola*, with sparse shrubs including *Podocarpus lawrencei*, *Prostanthera cuneata, Melicytus* sp. 'Snowfields'

Plate a51: Rocky outcrops with skeletal soils in subalpine and alpine parts of Kosciuszko NP usually have a sparse cover of herbs and low shrubs. This example is at Kiandra in Kosciuszko NP where the shrub component was temporarily removed by the 2003 fire.

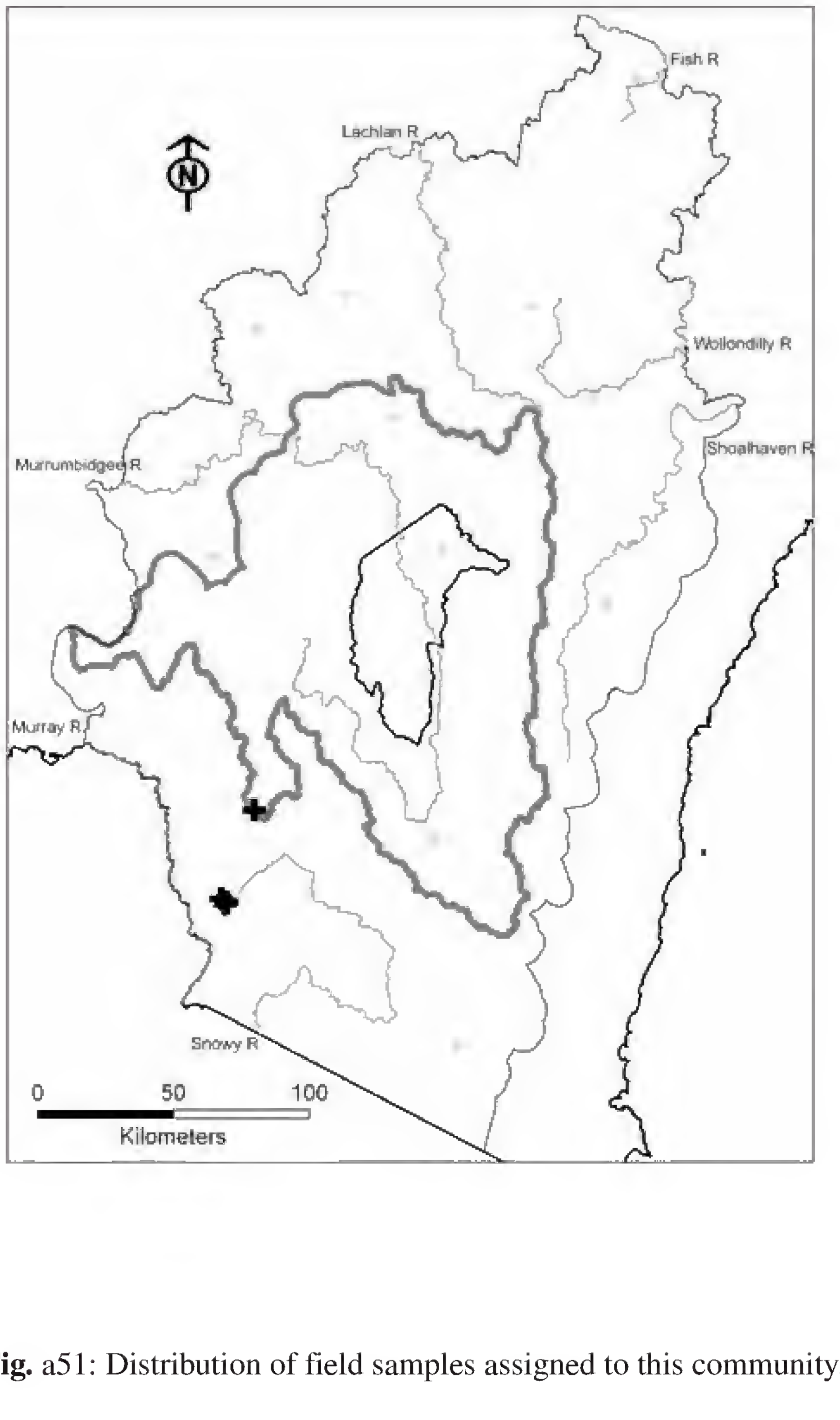

Fig. a51: Distribution of field samples assigned to this community.

and *Acrothamnus montanus.* Plant cover is generally minimal. This community occurs on cliffs and other rocky outcrops from Mt. Buller in Victoria to Kiandra in NSW. It is especially common on the higher peaks of the Kosciuszko Main Range and the Mt. Jagungal area. Herbs and sedges such as *Brachyscome nivalis*, *Brachyscome rigidula*, *Crassula sieberiana* and *Luzula novae-cambriae* occur in most examples and are rarely found in other communities in the Australian Alps bioregion.

Characteristic Species:

Species	C/A	Freq	C/AO	FreqO	Fid
Aciphylla glacialis	1	20	1	<1	P
Acrothamnus montanus	1	80	1	1	P
Argyrotegium fordianum	1	20	1	<1	P
Argyrotegium mackayi	1	20	1	<1	P
Asperula pusilla	1	20	1	<1	P
Brachyscome nivalis	1	40	1	<1	P
Celmisia pugioniformis	2	40	1	2	P
Craspedia adenophora	1	20	1	<1	P
Craspedia aurantia	1	40	1	2	P
Craspedia maxgrayi	1	20	1	<1	P
Deyeuxia crassiuscula	1	60	1	<1	P
Epilobium billardierianum	1	60	1	2	P
Erigeron nitidus	1	20	1	<1	P
Ewartia nubigena	1	60	1	<1	P
Gentianella muelleriana subsp. *alpestris*	1	20	1	<1	P
Luzula novae-cambriae	1	20	1	<1	P
Lycopodium fastigiatum	1	40	1	<1	P
Melicytus sp. 'Snowfields'	1	60	1	3	P
Microseris lanceolata	1	60	1	7	P
Nematolepis ovatifolia	2	40	3	<1	P
Olearia brevipedunculata	1	20	1	<1	P
Oreomyrrhis brevipes	1	20	0	0	P
Oreomyrrhis eriopoda	1	80	1	13	P
Ozothamnus secundiflorus	1	20	1	<1	P
Poa costiniana	1	60	2	5	P
Poa fawcettiae	3	60	3	2	P
Podocarpus lawrencei	2	80	2	<1	P
Polystichum proliferum	1	80	1	7	P
Prostanthera cuneata	2	40	2	<1	P
Rytidosperma alpicola	1	100	1	<1	P
Rytidosperma nudiflorum	1	40	1	2	P
Saxipoa saxicola	1	20	1	<1	P
Scleranthus singuliflorus	1	60	1	<1	P
Senecio pectinatus var. *major*	1	20	1	<1	P
Senecio pinnatifolius var. *alpinus*	1	60	1	3	P
Trisetum spicatum	1	60	1	3	P
Acaena novae–zelandiae	1	40	1	28	C
Carex breviculmis	1	60	1	13	C
Crassula sieberiana	1	40	1	6	C
Viola betonicifolia	1	80	1	27	C

Threatened communities: Nil.

Equivalent vegetation types: *Brachycome nivalis – Danthonia alpicola* alliance (Costin 1954); *Poa hothamensis* (rocky) grassland, Unit 13 (McDougall 1982); *Brachyscome – Austrodanthonia* tall alpine herbfield (Costin *et al.* 2000); Community 51 [*Austrodanthonia alpicola – Grevillea australis* open heathland] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.80), *Hypochaeris radicata* (0.40).

Threats: Examples of this community occurring on cliffs above Blue Lake in Kosciuszko NP are possibly threatened by recreational rock climbers. Elsewhere, it may be damaged by tourists accessing rocky outcrops for better views, but the overall threat to the community from these activities is currently low.

Reservation status: Likely to be entirely within Kosciuszko NP.

Extent of clearing: Nil.

References: Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); Costin, A.B., Gray, M., Totterdell, C.J. & Wimbush D.J. (2000) Kosciuszko alpine flora. (CSIRO Publishing: Collingwood); McDougall, K.L. (1982) The alpine vegetation of the Bogong high plains. Environmental studies publication no. 357. Ministry for Conservation: Melbourne; McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

a54: *Podocarpus lawrencei – Pimelea ligustrina* subsp. *ciliata* heathland of screes and boulder-fields of the Australian Alps bioregion

Scientific Name: *Podocarpus lawrencei – Pimelea ligustrina* subsp. *ciliata / Polystichum proliferum*

Number of samples:	2
Richness [mean (±SD)]:	15 (6)
Slope (degrees):	(6) 7–8 (8)
Altitude (m asl):	(1766) 1798–1861 (1892)
Ave. Annual Rainfall (mm):	(2062) 2096–2164 (2198)
Temp. Annual Range (°C):	(20.7) 20.9–21.3 (21.5)

Vegetation Description: Community a54 is a closed shrubland dominated by *Podocarpus lawrencei.* It occurs in areas of minimal soil development and abundant boulders in the alpine and subalpine areas of Victoria (Bogong High Plains, Mt. Hotham area, Mt. Howitt, Mt. Buffalo, Cobberas and Crosscut Saw) and NSW (between Mt. Kosciuszko and Mt. Jagungal, and the steep slopes of the Tumut valley in the vicinity of Cabramurra). Scree slopes containing *Podocarpus lawrencei* in the ACT may also be referable to this community, but further sampling is required to confirm this. Examples have been recorded on metamorphic substrates, where *Podocarpus lawrencei* layers over large rock slabs, on granite boulder streams and outcrops and on basalt scree. The species composition of plots depends on the location of drainage features, which often pass under the boulders. Species characteristic of wetlands (e.g. *Richea continentis*) may therefore be found in damp parts of the community. Species richness is commonly low, and in sites with large rocks and no exposed soil there may be only a few species per plot.

This community is highly restricted and usually found in screes and bounder fields amongst Community u158 [*Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion*] or Community a46 [*Prostanthera cuneata – Orites lancifolius – Nematolepis ovatifolia heathland of the Australian Alps bioregion*]. After the 2003 fires, the diversity of many burnt *Podocarpus lawrencei* heathlands increased. *Pelargonium helmsii*, a species rarely recorded prior to 2003, was found to be common in many burnt *Podocarpus lawrencei* dominated heathlands in Kosciuszko NP. A population of *Senecio velleioides*, normally a wet sclerophyll forest species occurring from the central coast in NSW south to Tasmania, was located in this community two years after the fire at 1880 metres above sea level on Blue Cow Mountain. This was the first record for this species in treeless vegetation in the Australian Alps bioregion. The community is the primary habitat for the Mountain Pygmy-possum (*Burramys parvus*), an endangered marsupial.

Characteristic Species:

Species	C/A	Freq	C/AO	FreqO	Fid
Argyrotegium fordianum	1	50	1	<1	P
Baeckea gunniana	2	50	2	1	P
Epilobium billardierianum	1	50	1	2	P
Erigeron nitidus	1	100	1	<1	P
Grevillea australis	2	50	2	2	P

Lycopodium fastigiatum	1	50	1	<1	P
Nematolepis ovatifolia	2	100	3	<1	P
Olearia brevipedunculata	1	50	1	<1	P
Olearia phlogopappa	1	50	1	3	P
Orites lancifolius	2	100	3	<1	P
Pimelea axiflora subsp. *alpina*	1	50	1	<1	P
Pimelea ligustrina subsp. *ciliata*	1	100	1	<1	P
Poa hiemata	1	50	2	2	P
Podocarpus lawrencei	4	100	2	<1	P
Polystichum proliferum	1	100	1	7	P
Prostanthera cuneata	3	100	2	<1	P
Richea continentis	1	50	2	<1	P
Carex breviculmis	1	50	1	13	C
Deyeuxia monticola	1	50	1	6	C
Oreomyrrhis eriopoda	1	50	1	13	C
Senecio gunnii	1	50	1	9	C

Threatened communities: Nil, but possibly eligible for listing.

Equivalent vegetation types: part of *Oxylobium ellipticum – Podocarpus alpinus* alliance (Costin 1954); *Podocarpus lawrencei* association (McVean 1969); *Podocarpus* heathland, Unit 1 (McDougall 1982); *Podocarpus* heathland, subcommunity 1.1 (Walsh *et al.* 1984); Community 54 [*Podocarpus lawrencei closed heathland*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Acetosella vulgaris* (0.5).

Threats: Surveys of regeneration following the 2003 fires suggest that recovery of many stands will be slow and patchy, and some may not recover at all in the short term. Basal regeneration of *Podocarpus lawrencei* has been observed in some populations in the ACT and the Cobberas in Victoria (Carey *et al.* 2003, Tolsma *et al.* 2004) but none appears to have occurred in Kosciuszko NP (Williams *et al.* 2008). Resprouting of partially burnt stems did occur throughout its range but it tended to be rare and much of the regeneration subsequently died. Seedlings were observed in the summer following the fire, but these have been rare or patchy at some sites.

Dendrochronological research on *Podocarpus lawrencei* indicates that plants are up to 400 years old (McDougall *et al.* 2012). Since the plants are obligate seeders (in NSW at least), catastrophic fires must be rare in this community. Too frequent fire is therefore a grave threat to this community and the Mountain Pygmy-possum.

Reservation status: All within Kosciuszko NP.

Extent of clearing: Nil.

References: Carey, A., Evans, M., Hann, P., Lintermans, M., MacDonald, T., Ormay, P., Sharp, S., Shorthouse, D. & Webb, N. (2003) Wildfires in the ACT 2003: Report on initial impacts on natural ecosystems . Technical Report 17, Wildlife Research and Monitoring, Environment ACT, Canberra; Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); McDougall, K.L. (1982) The alpine vegetation of the Bogong high plains. Environmental studies publication no. 357. Ministry for Conservation: Melbourne; McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; McDougall, K.L., Brookhouse, M. & Broome, L.S. (2012) Dendroclimatological investigation of mainland Australia's only alpine conifer, *Podocarpus lawrencei* Hook.f. *Dendrochronologia* 30: 1–9; McVean, D.N. (1969) Alpine vegetation of the central Snowy Mountains of New South Wales. *Journal of Ecology* 57: 67–86; Tolsma, A., Coates, F. & Sutter, G. (2004) Recovery of Mountain Plum-Pine Shrubland After Fire (Cobberas). Arthur Rylah Institute for Environmental Research Technical Report No. 153. Department of Sustainability and Environment, Victoria; Walsh, N.G., Barley, R.H. & Gullan, P.K. (1984) The alpine vegetation of Victoria (excluding the Bogong high plains), volume 1. Environmental studies publication no. 376. Department of Conservation, Forests and Lands: Melbourne; Williams, R.J., Wahren, C-H., Tolsma, A.D., Sanecki, G.M., Papst, W.A., Myers, B.A., McDougall, K.L., Heinze, D.A. & Green, K. (2008) Large fires in Australian alpine landscapes: their part in the historical fire regime and their impacts on alpine biodiversity. *International Journal of Wildland Fire* 17: 793–808.

Plate a54: Periglacial activity has resulted in the deposition of extensive piles of boulders (of granite or basalt) in Kosciuszko NP. Community a54, dominated by *Podocarpus lawrencei*, is characteristic of this habitat; this example on basalt near Happy Jacks Plain.

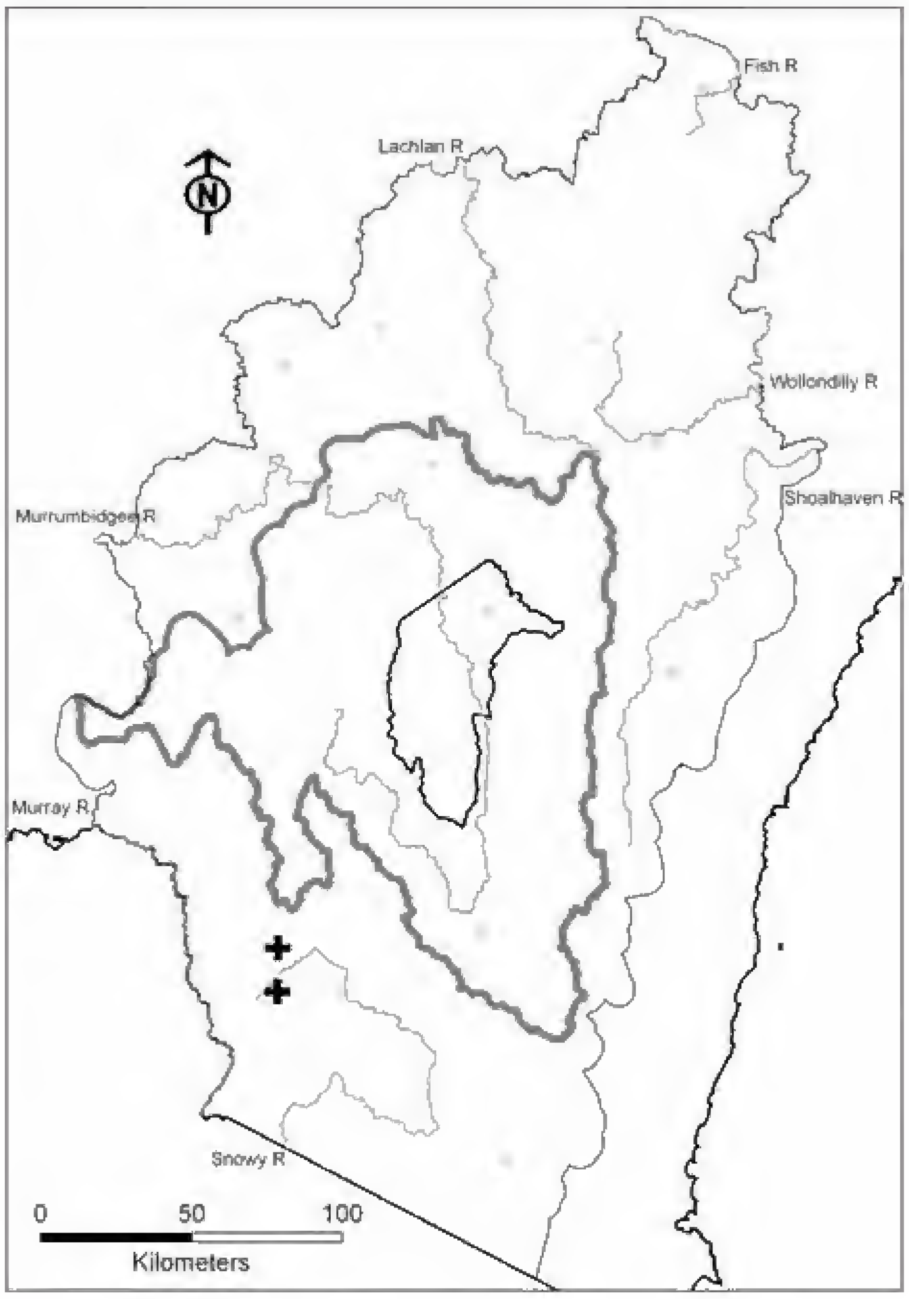

Fig. a54: Distribution of field samples assigned to this community.

g36: *Leptospermum micromyrtus – Kunzea muelleri – Kunzea ericoides* dry heathland on skeletal ridges primarily of the Namadgi region

Scientific Name: *Leptospermum micromyrtus – Kunzea muelleri – Kunzea ericoides / Carex breviculmis – Gonocarpus tetragynus*

Number of samples:	8
Richness [mean (±SD)]:	15 (4)
Slope (degrees):	(3) 11–23 (30)
Altitude (m asl):	(1123) 1370–1461 (1634)
Ave. Annual Rainfall (mm):	(928) 1043–1137 (1357)
Temp. Annual Range (°C):	(22.1) 23.4–23.9 (25.2)

Vegetation Description: Community g36 is a dense shrubland interspersed with large expanses of unvegetated rock outcrop. Dominant species include *Leptospermum micromyrtus*, *Kunzea ericoides*, *Calytrix tetragona*, *Kunzea muelleri* and *Leionema lamprophyllum*. *Epacris robusta* and *Oxylobium ellipticum* may also be locally common, and *Eucalyptus cinerea* subsp. *triplex* is an emergent (up to 10 metres tall) at one site. *Carex breviculmis*, *Veronica perfoliata*, *Gonocarpus tetragynus* and *Poa* spp. are common ground cover elements. Species such as *Pelargonium australe*, *Trachymene composita* and the endangered *Dampiera fusca* are likely to be ephemeral components that increase in abundance after fire.

This community has been recorded on granite outcrops at Booroomba Rocks in the ACT, the NSW side of Mt. Coree on the NSW / ACT border (Brindabella NP) and in Yaouk NR in NSW. It was identified as *Montane / Sub-Alpine Dry Rocky Shrubland* by Gellie (2005). Modelling by Gellie (2005), which suggested that the community extends from the ACT to the higher parts of Kosciuszko NP to the south-west (in the vicinity of the Main Range), is not supported by subsequent plot sampling. While the exact distribution of this community is uncertain because of undersampling (a consequence of the remoteness of the areas in which it occurs), the distribution of one of its character species gives a clue to the likely distribution. The variant of *Asterolasia trymalioides* that occurs in this community is likely to be recognized at subspecific rank (K. McDougall, OEH, pers. comm.). It is found at Booroomba Rocks in Namadgi NP and granite outcrops along the ACT / NSW border (e.g. Mt. Kelly, Mt. Scabby) to Yaouk NR. This variant also occurs in Tinderry NR (Twin Peaks) in similar habitat and with many of the characteristic species listed below, however its relationship to this plant community has not been investigated through plot sampling.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Asterolasia aff. *trymalioides*	2	25	2	<1	P
Baeckea utilis	1	25	2	2	P
Bulbine glauca	1	25	1	<1	P
Callistemon pallidus	1	25	1	<1	P
Calytrix tetragona	3	25	2	1	P
Carex breviculmis	2	63	1	13	P
Deyeuxia monticola	1	38	1	5	P
Epacris robusta	2	25	0	0	P
Kunzea ericoides	3	75	2	4	P
Kunzea muelleri	3	75	2	<1	P
Leptospermum micromyrtus	2	88	1	<1	P
Leptospermum namadgiensis	2	25	0	0	P
Leucopogon attenuatus	2	38	1	1	P
Oxylobium ellipticum	2	38	1	4	P
Pelargonium australe	1	38	1	<1	P
Poa induta	2	38	3	6	P
Prostanthera decussata	2	25	2	<1	P
Rytidosperma fulvum	2	25	2	1	P
Thelymitra spp.	1	25	1	3	P

Plate g36: Community g36 is a shrubland of granite outcrops dominated by Leptospermum micromyrtus and *Kunzea muelleri*; This example is at Booroomba Rocks, Namadgi NP.

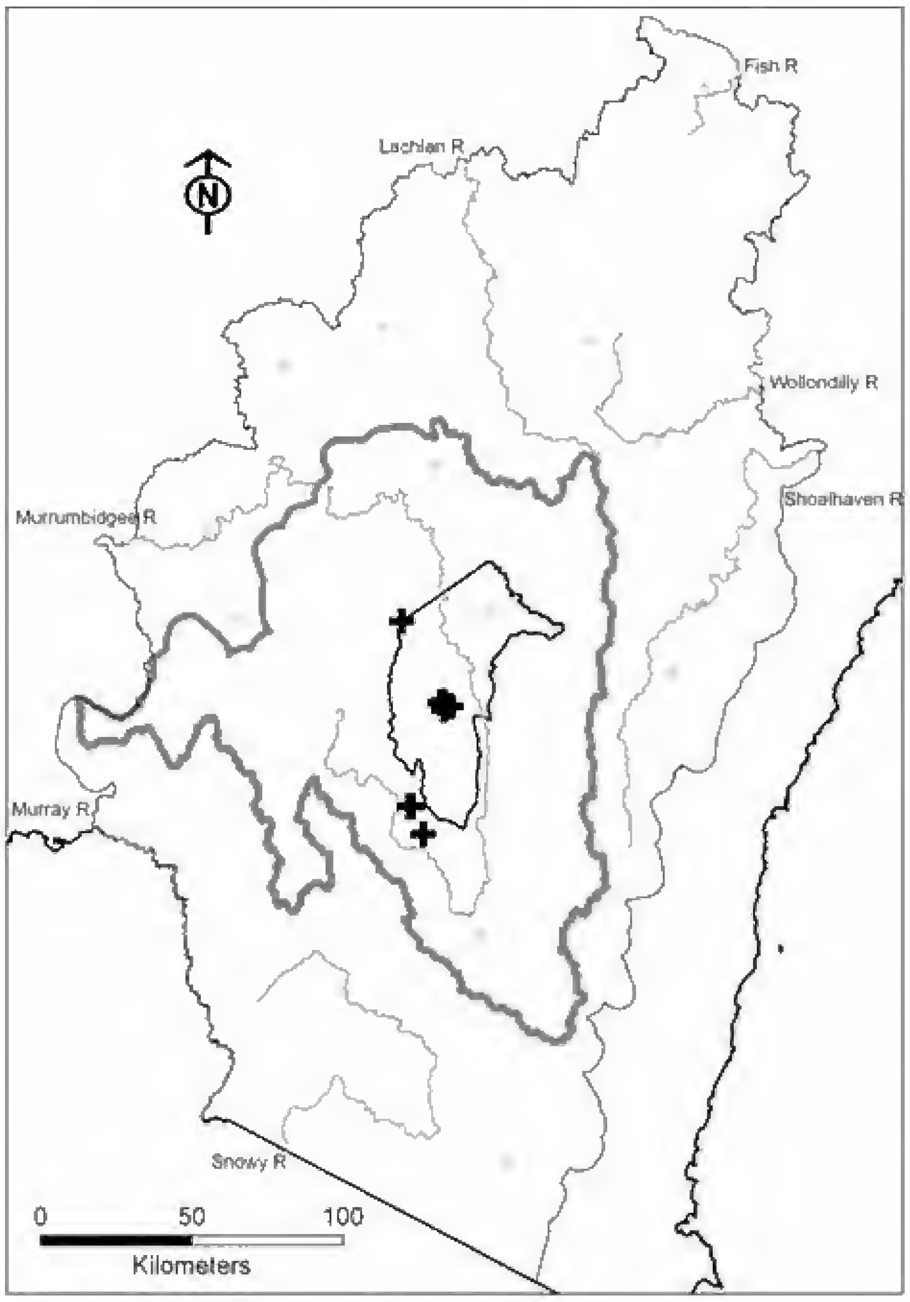

Fig. g36: Distribution of field samples assigned to this community

Trachymene composita	3	25	1	<1	P
Veronica perfoliata	1	38	1	4	P
Gonocarpus tetragynus	2	50	2	48	C

Threatened communities: Nil.

Equivalent vegetation types: Equivalent to Community VG36 [*Montane / Sub-Alpine Dry Rocky Shrubland*] (Gellie 2005).

Frequently occurring weeds: *Hypochaeris glabra*, *Hypochaeris radicata*, *Vulpia bromoides*, *Vulpia myuros* f. *megalura* (all 0.20).

Threats: Not considered to have any significant threats.

Reservation status: Likely to be entirely within conservation reserves; recorded from Namadgi NP, Brindabella NP and Yaouk NR.

Extent of clearing: Nil.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Class: Alpine Bogs and Fens

a2: *Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum* wet heathland of the Australian Alps bioregion (Bog)

Scientific Name: *Baeckea gunniana – Epacris paludosa – Richea continentis / Carex gaudichaudiana – Sphagnum cristatum*

Number of samples:	38
Richness [mean (±SD)]:	20 (6)
Slope (degrees):	(0) 2–9 (20)
Altitude (m asl):	(1149) 1377–1741 (2004)
Ave. Annual Rainfall (mm):	(999) 1383–2051 (2488)
Temp. Annual Range (°C):	(20.3) 21.5–23.6 (24.8)

Vegetation Description: Community a2 generally occurs as a low closed wet heathland dominated by *Baeckea gunniana*, *Epacris paludosa* and *Richea continentis*, with intervening areas dominated by *Sphagnum cristatum* and associated herbs (e.g. *Astelia alpina*, *Astelia psychrocharis*, *Baloskion australe*, *Carex gaudichaudiana*, *Carpha nivicola*, *Celmisia* spp. (*Celmisia pugioniformis*, *Celmisia 'pulchella'* ms., *Celmisia tomentosa*), *Diplaspis nivis*, *Empodisma minus*, *Erigeron paludicola*, *Oreobolus distichus*, *Oschatzia cuneifolia* and *Poa costiniana*. At lower elevations this community is generally dominated by shrubs such as *Baeckea gunniana*, *Epacris paludosa*, *Richea continentis*, *Callistemon pityoides* and *Epacris breviflora,* with *Epacris glacialis* becoming more frequent at higher elevations. It is found mainly in broad valleys, but also in seepage zones on slopes of low relief and along margins of smaller watercourses. Free water, either as pools or as slow-flowing streams is usually present.

This community is widespread from the Brindabella Ranges in the ACT through to Kosciuszko NP in NSW (and possibly extending into the South Eastern Highlands at lower altitudes). In Victoria it is known from The Cobberas and across the Bogong High Plains, with outlying examples on the Mt. Buffalo plateau. In the upper Murrumbidgee catchment, examples of this community are generally small, occurring in linear strips along creeks or as patches of less than 100 metres^2. Most are found in conservation reserves (Kosciuszko NP, Bimberi NR, Namadgi NP), with limited occurrences on State Forest and private land east of Tumbarumba.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Aciphylla simplicifolia	1	29	1	2	P
Asperula gunnii	1	45	1	4	P
Astelia psychrocharis	1	32	1	<1	P
Baeckea gunniana	1	79	2	<1	P
Baloskion australe	1	55	1	1	P
Brachyscome obovata	1	39	1	<1	P
Carex gaudichaudiana	1	95	2	3	P
Carpha nivicola	1	29	1	<1	P
Celmisia pugioniformis	1	32	1	2	P
Empodisma minus	3	97	2	2	P
Epacris glacialis	2	26	1	<1	P
Epacris gunnii	1	24	1	2	P
Epacris paludosa	2	71	2	<1	P
Epilobium gunnianum	1	39	1	1	P
Erigeron paludicola	1	37	1	<1	P
Gonocarpus micranthus	1	29	1	2	P
Hakea microcarpa	1	21	1	3	P
Luzula modesta	1	53	1	2	P
Oreobolus distichus	1	50	1	<1	P
Oreomyrrhis ciliata	1	50	1	2	P
Oschatzia cuneifolia	1	24	1	<1	P
Poa costiniana	2	95	2	4	P
Ranunculus pimpinellifolius	1	24	1	1	P
Richea continentis	3	61	1	<1	P
Rytidosperma nivicola	1	24	1	<1	P
Sphagnum cristatum	4	89	2	<1	P

Threatened communities: TSC Act 1995 – *Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions*; EPBC Act 1999 – *Alpine Sphagnum Bogs and Associated Fens.*

Equivalent vegetation types: *Epacris paludosa – Sphagnum cymbifolium* alliance and *Carex gaudichaudiana – Sphagnum cymbifolium* alliance and *Epacris breviflora – Blindia robusta* alliance (Costin 1954); *Sphagnum – Richea – Astelia* association (McVean 1969); types 4a and 4b (Helman & Gilmour 1985); groups 11 and 12 (Helman *et al.* 1988), combination of Community 2 [*Richea continentis – Carpha nivicola – Sphagnum cristatum wet heathland*] and Community 3 [*Baeckea gunniana – Callistemon pityoides – Sphagnum cristatum wet heathland*] (McDougall & Walsh 2007).

Frequently occurring weeds: This community is generally low in weed diversity with the most common being *Trifolium repens* (0.07).

Threats: Historically this community was heavily degraded by cattle and sheep grazing, and by fire used for grazing management. Many examples were drained for water management during the Snowy Hydro Scheme and some were destroyed in early ski resort development. Damage still occurs as a result of trampling by feral horses, deer and pigs. Some freehold examples are still affected by domestic grazing practices.

Reservation status: Most examples of this community are in Kosciuszko NP and Namadgi NP. A few are in State Forest and freehold land adjoining Kosciuszko NP.

Extent of clearing: Not assessed. Very little has been cleared but all has been degraded.

References: Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); Helman, C.E. & Gilmour, P.M. (1985) Treeless vegetation above 1,000 metres altitude in the A.C.T. Unpublished report. Conservation Council of the Southeast Region and Canberra: Canberra; Helman, C.E., Gilmour, P.M., Osborne, W.S. & Green, K. (1988) An ecological survey of the upper Cotter catchment wilderness area, Namadgi National Park, ACT. Unpublished report. Conservation Council of the South-east Region and Canberra, Canberra; McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

Plate a2: Community a2 (also known as bogs or peatlands) develops where drainage is impeded in the Australian Alps and surrounds. Examples may contain a range of tall or short shrubs but the moss and herbaceous layer is remarkably similar at most sites; this Richea continentis-dominated example near Mt Jagungal, Kosciuszko NP.

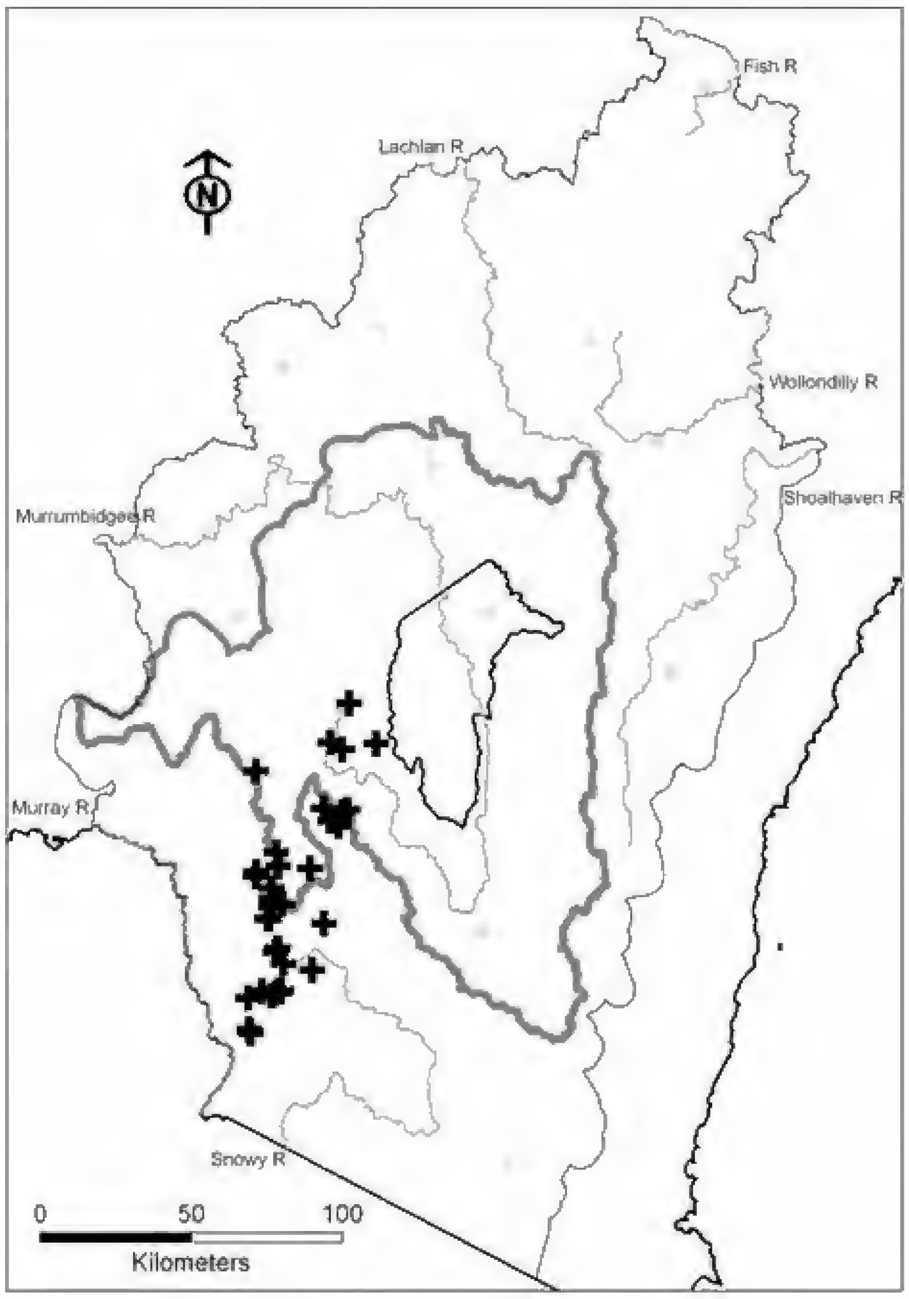

Fig. a2: Distribution of field samples assigned to this community.

a7: *Ranunculus pimpinellifolius – Gonocarpus micranthus* herbfield of wetland margins in the Australian Alps bioregion

Scientific Name: *Ranunculus pimpinellifolius – Gonocarpus micranthus – Carex gaudichaudiana – Cotula alpina – Hydrocotyle algida – Montia australasica*

Number of samples:	2
Richness [mean (±SD)]:	20 (8)
Slope (degrees):	(2) 4–7 (9)
Altitude (m asl):	(1577) 1582–1591 (1595)
Ave. Annual Rainfall (mm):	(1775) 1817–1902 (1944)
Temp. Annual Range (°C):	(21.8) 21.9–22 (22)

Vegetation Description: Community a7 is a herbfield occuring in broad valleys or around seepage zones on flat ground anywhere in the subalpine zone where soils are relatively deep and permanently sodden (but not inundated); often found on sites with basaltic parent material. Forbs such as *Hypericum japonicum*, *Ranunculus pimpinellifolius*, *Gonocarpus micranthus*, *Nertera granadensis* and *Epilobium curtisiae* are the usual dominants and form a dense mat of overlapping foliage.

Examples of this community are often small (a few metres^2) and adjoin Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*]. It has been recorded from Boggy Plain near Tantangara, Long Plain and Bogong Plain near Mt. Jagungal (all in the upper Murrumbidgee catchment) but undoubtedly commonly occurs elsewhere within the subalpine area and possibly into the ACT. It is also found in the Victorian high country.

Characteristic Species:

Species	C/A	**Freq**	**C/A O**	**FreqO**	**Fid**
Agrostis venusta	1	50	1	<1	P
Baeckea gunniana	1	50	2	1	P
Brachyscome tadgellii	1	50	1	<1	P
Carex cephalotes	1	50	1	<1	P
Carex echinata	1	50	1	<1	P
Carex gaudichaudiana	3	100	2	4	P
Cotula alpina	2	100	1	1	P
Epilobium curtisiae	1	50	1	<1	P
Epilobium gunnianum	1	100	1	1	P
Gonocarpus micranthus	2	100	1	2	P
Hydrocotyle algida	2	100	1	1	P
Isolepis subtilissima	2	50	1	<1	P
Juncus falcatus	2	50	1	<1	P
Luzula modesta	1	50	1	2	P
Montia australasica	2	100	1	1	P
Myriophyllum alpinum	2	50	1	<1	P
Myriophyllum pedunculatum	1	50	1	<1	P
Nertera granadensis	1	50	1	<1	P
Olearia algida	1	50	1	<1	P
Oreobolus pumilio	1	50	2	<1	P
Oreomyrrhis ciliata	2	100	1	2	P
Poa costiniana	1	100	2	5	P
Ranunculus millanii	1	100	1	<1	P
Ranunculus pimpinellifolius	3	100	1	1	P
Richea continentis	1	50	2	<1	P
Rytidosperma nivicola	1	50	1	<1	P
Acaena echinata	1	50	1	9	C
Hypericum japonicum	1	50	1	4	C

Threatened communities: TSC Act 1995 – *Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions.*

Plate a7: Community a7 is typically very small in extent, being found at the margins of various wetlands; this example at Long Plain in Kosciuszko NP.

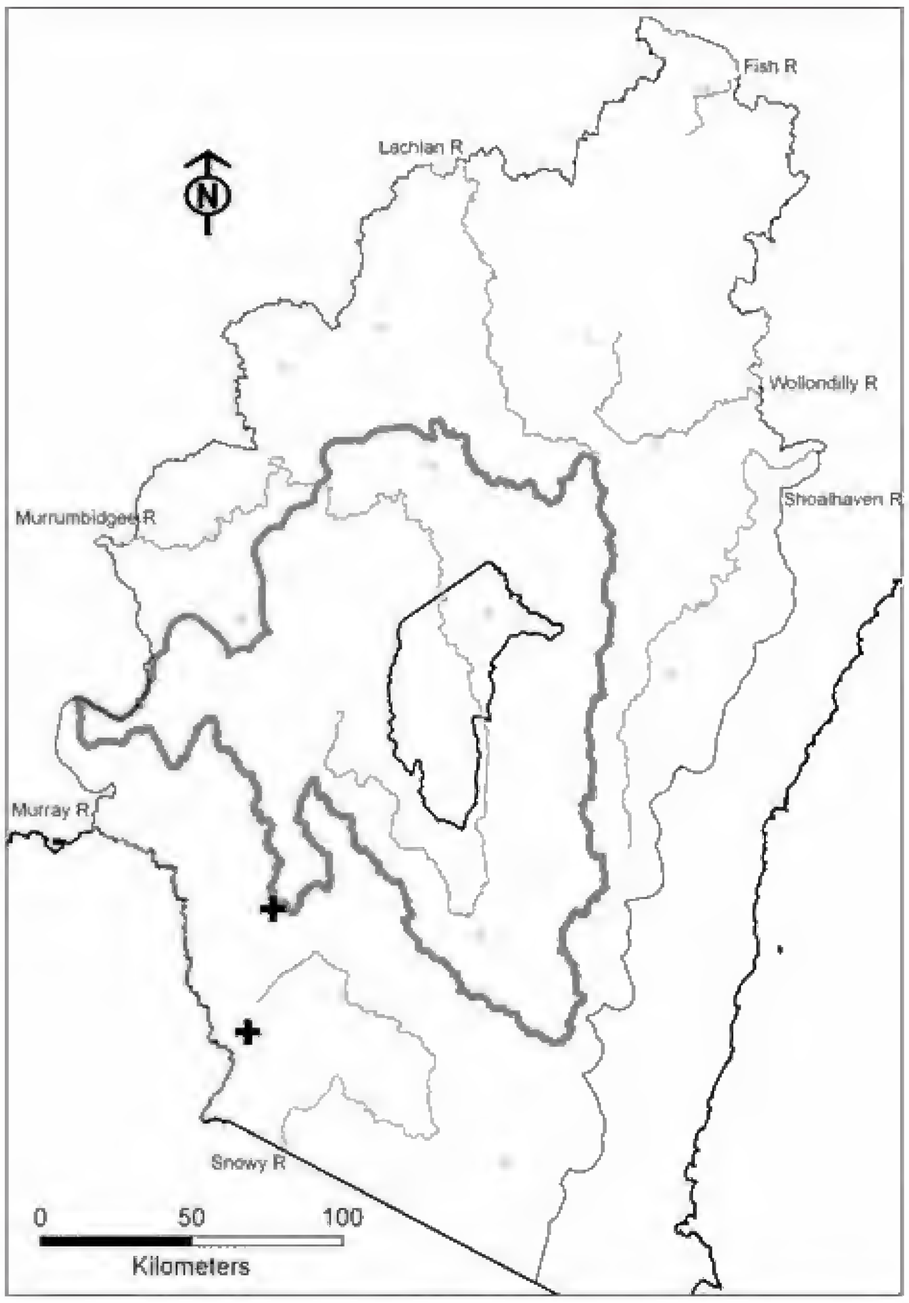

Fig. a7: Distribution of field samples assigned to this community.

Equivalent vegetation types: Community 7 [*Hypericum japonicum – Ranunculus pimpinellifolius herbfield*] (McDougall & Walsh 2007).

Frequently occurring weeds: *Taraxacum officinale* (0.5), *Trifolium repens* (0.5).

Threats: A relatively high weed cover in plots (particularly *Acetosella vulgaris*, *Cerastium glomeratum*, *Holcus lanatus* and *Trifolium repens*) is indicative of past disturbance. Sites in NSW may be affected by pigs and are especially vulnerable to trampling by feral horses.

Reservation status: Possibly all within Kosciuszko NP.

Extent of clearing: Nil, but probably severely damaged by trampling when grazed by domestic stock.

Reference: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

a8: *Carex gaudichaudiana – Myriophyllum pedunculatum – Deschampsia cespitosa* sedgeland of the Australian Alps bioregion (Fen)

Scientific Name: *Carex gaudichaudiana – Myriophyllum pedunculatum – Deschampsia cespitosa – Isolepis montivaga*

Number of samples:	7
Richness [mean (±SD)]:	12 (6)
Slope (degrees):	(1) 2–4 (13)
Altitude (m asl):	(1281) 1559–1760 (1920)
Ave. Annual Rainfall (mm):	(1525) 1758–2040 (2405)
Temp. Annual Range (°C):	(20.7) 21.4–21.9 (23.5)

Vegetation Description: Community a8 is a wet sedgeland (fen) dominated by the sedge *Carex gaudichaudiana*, making it one of the most immediately recognisable of alpine/subalpine communities. Typically, sites are inundated through most (if not all) summer with water depths up to approximately 15 centimetres. Examples tend to be species-poor but in some areas *Brachyscome obovata*, *Carex echinata*, *Deschampsia cespitosa*, *Epilobium gunnianum*, *Isolepis montivaga* and *Myriophyllum pedunculatum* are reasonably common. *Sphagnum cristatum* often occupies any ground raised slightly above the bed of the fen. *Poa costiniana* is a frequent component of this community but is typically present only at the margins of the zone of permanent inundation. This community is highly variable and poorly sampled.

This community is widespread in valleys and low saddles in Kosciuszko NP (extending into the alpine zone) and subalpine valleys of the ACT. It is known from Victoria where it is far less common. Examples in the upper Murrumbidgee catchment are often small and form part of a mosaic with Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*] in areas of impeded drainage, and Community a14 [*Poa constiniana – Carex gaudichaudiana subalpine valley grassland of the Australian Alps bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Asperula gunnii	1	43	1	5	P
Baloskion australe	1	43	1	2	P
Brachyscome obovata	1	43	1	1	P
Cardamine astoniae	2	29	1	<1	P
Carex echinata	2	29	1	<1	P
Carex gaudichaudiana	4	100	2	4	P
Carpha nivicola	1	29	1	<1	P
Deschampsia cespitosa	1	57	1	<1	P
Epilobium gunnianum	1	43	1	1	P
Isolepis montivaga	1	29	1	<1	P

Juncus falcatus	1	29	2	<1	P
Luzula modesta	1	29	1	2	P
Montia australasica	1	29	1	1	P
Myriophyllum pedunculatum	1	57	1	<1	P
Oreomyrrhis ciliata	2	29	1	2	P
Poa costiniana	1	71	2	5	P
Ranunculus pimpinellifolius	2	29	1	1	P
Richea continentis	1	29	2	<1	P
Sphagnum cristatum	2	57	3	1	P

Threatened communities: TSC Act 1995 – *Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions*; EPBC Act 1999 – *Alpine Sphagnum Bogs and Associated Fens*.

Equivalent vegetation types: *Carex gaudichaudiana* alliance (Costin 1954); *Carex – Drepanocladus* association (McVean 1969); Vegetation Type 6a (Helman & Gilmour 1985); Fen (Costin *et al.* 2000); Community 8 [*Fen*] (McDougall & Walsh 2007).

Frequently occurring weeds: No weeds have been recorded in plots in this community.

Threats: The weed *Myosotis caespitosa*, although not recorded in plots, is abundant at a few sites in Kosciuszko NP (e.g. Boggy Plain, Ogilvies Plain) and may threaten the integrity of this community.

Reservation status: Possibly all within Kosciuszko and Namadgi NPs.

Extent of clearing: Nil, but this community was probably highly degraded by domestic grazing. The dominant species, *Carex gaudichaudiana*, is noted for its high palatability (Van Rees & Holmes 1986).

References: Costin, A.B. (1954) A study of the ecosystems of the Monaro region of New South Wales. (Government Printer: Sydney); Costin, A.B Helman, C.E. & Gilmour, P.M. (1985) Treeless vegetation above 1,000 metres altitude in the A.C.T. Unpublished report. Conservation Council of the Southeast Region and Canberra: Canberra; McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57; McVean, D.N. (1969) Alpine vegetation of the central Snowy Mountains of New South Wales. *Journal of Ecology* 57: 67–86; Van Rees, H. & Holmes, J.H.G. (1986) The botanical composition of the diet of free-ranging cattle on an alpine range in Australia. *Journal of Range Management* 39: 392–395.

Plate a8: Subalpine and alpine areas where water lies for long periods are usually dominated by *Carex gaudichaudiana*. They are commonly known as fens. Species richness is a function of the duration of inundation.

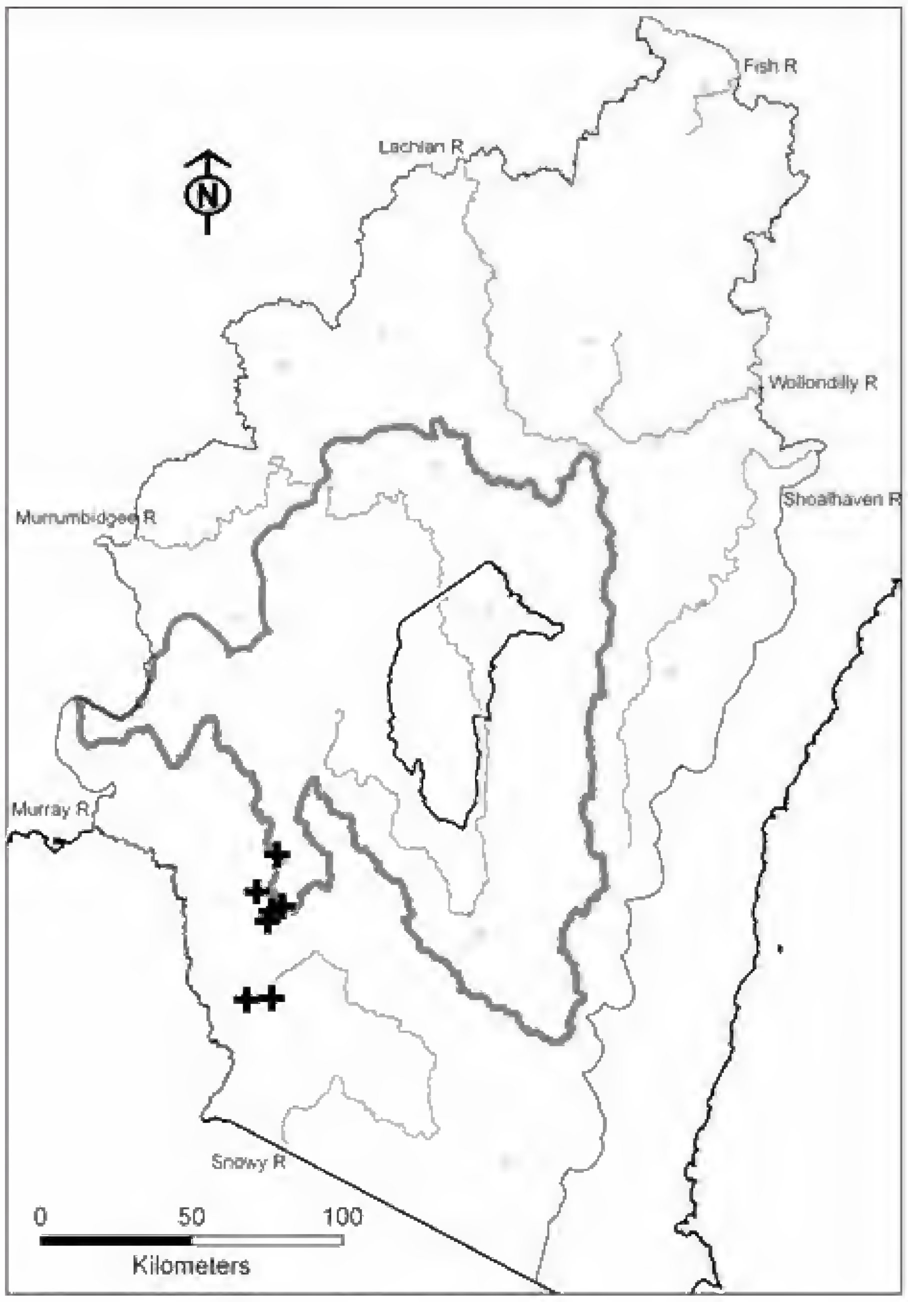

Fig. a8: Distribution of field samples assigned to this community.

Formation: Rainforests

Class: Cool Temperate Rainforests

g172: Black Sassafras temperate rainforest of wet sheltered slopes in the Australian Alps and Bondo subregion of the South Eastern Highlands bioregions

Scientific Name: *Atherosperma moschatum – Dicksonia antarctica / Polystichum proliferum – Blechnum fluviatile – Australina pusilla – Asplenium flabellifolium*

Number of samples:	2
Richness [mean (±SD)]:	14 (3)
Slope (degrees):	(8) 10–13 (14)
Altitude (m asl):	(1037) 1053–1084 (1099)
Ave. Annual Rainfall (mm):	(1104) 1126–1170 (1192)
Temp. Annual Range (°C):	(25) 25.1–25.2 (25.2)

Vegetation Description: Community g172 is a rare rainforest community to about 20 metres high, dominated by *Atherosperma moschatum*. The shrub layer is dominated by *Dicksonia antarctica*, with a sparse groundlayer dominated by *Polystichum proliferum*, *Blechnum fluviatile*, *Australina pusilla*, *Asplenium flabellifolium*, *Urtica incisa* and *Viola hederacea*.

This community occurs in deep east facing valleys and gorges, mainly as a narrow band along drainage lines usually only a few metres wide and often overtopped by the canopy of adjacent Community u40 [*Alpine Ash tall wet sclerophyll open forest primarily of the Australian Alps bioregion*], and occasionally, u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo subregion of the South Eastern Highlands and the northern Australian Alps bioregions*]. However, the structure and floristics of these communities are distinct and they do not intergrade.

Community g172 is found as isolated patches along creeks near Bogong Peaks (such as Stinking Creek and the upper Goobaragandra River), the Geehi Valley (Greening Australia 2011), and the Jacobs and Pinch River Gorges. While it is sampled only at higher elevations in the Murray catchment, within the study area it is found down to 700 metres above sea level, some 150 metres below the occurrence of *Eucalyptus delegatensis*. Stands in the Pinch River Gorge contain *Elaeocarpus holopetalus* (Doherty *et al.* 2011). A similar community also occurs in southern parts of Tallaganda SF east of the divide, and possibly in Gourock NP, although further sampling is required to quantify their relationship (J. Crooks, DPI, pers. comm.).

Fire is believed to have limited the extent of this community, as it is only found in locations that are protected from wildfires, which in the Australian Alps and Bondo subregion of the South Eastern Highlands are usually driven by strong north-westerly winds. Remnant stands do not seem to be burnt even in extreme events such as the 2003 wildfires that affected 70% of Kosciuszko NP.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Asplenium bulbiferum subsp. *gracillimum*	1	50	2	<1	P
Asplenium flabellifolium	2	100	1	9	P
Atherosperma moschatum	6	100	3	<1	P
Australina pusilla	2	100	2	1	P
Blechnum fluviatile	2	100	0	0	P
Dicksonia antarctica	4	100	3	2	P
Diplazium australe	2	50	2	<1	P
Histiopteris incisa	1	50	1	<1	P
Leptospernum grandifolium	1	50	3	2	P
Polystichum proliferum	2	100	1	7	P
Sambucus australasica	2	50	2	<1	P
Sambucus gaudichaudiana	2	50	1	<1	P
Tasmannia xerophila	1	50	1	2	P
Urtica incisa	1	100	1	2	P
Veronica subtilis	1	50	1	<1	P
Viola hederacea	1	100	2	19	P
Eucalyptus delegatensis	1	50	3	5	C
Poa helmsii	1	50	2	4	C
Rubus parvifolius	1	50	1	11	C
Tasmannia lanceolata	1	50	1	4	C

Threatened communities: Nil, but given its highly restricted distribution and the potential for wildfires to effect this community, it is possibly eligible for listing.

Equivalent vegetation types: This community was identified by Gellie (2005) as Community VG172 [*Kosciuszko Western Escarpment Cool Temperate Rainforest*].

Frequently occurring weeds: No weeds were recorded within plot samples.

Threats: Climate change and an increased incidence of hot fires may reduce the extent of the community.

Reservation status: Within the Upper Murrumbidgee catchment all sites known are in Kosciuszko NP.

Extent of clearing: Nil.

References: Doherty, M.D., Robertson, G., Corcoran, D. & Wright, G. (2011) Cool temperate rainforest in the Pilot wilderness area, Kosciuszko National Park: distribution, composition and impact of the 2003 fires. *Cunninghamia* 12: 119–127; Greening Australia (2011) Survey of southern sassafras (*Atherosperma moschatum*) in the Murphies Swamp area, Bogong Peak wilderness, Koskiuszko National Park. A report by Greening Australia capital region for the NSW Department of Environment, Climate Change and Water. Unpublished. February 2011; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate g172: Beneath the canopy of community g172, with *Dicksonia antarctica* beneath *Atherosperma moschatum*. 2.4 km east of Tin Mine Hut, Pilot Wilderness, Kosciuszko NP.

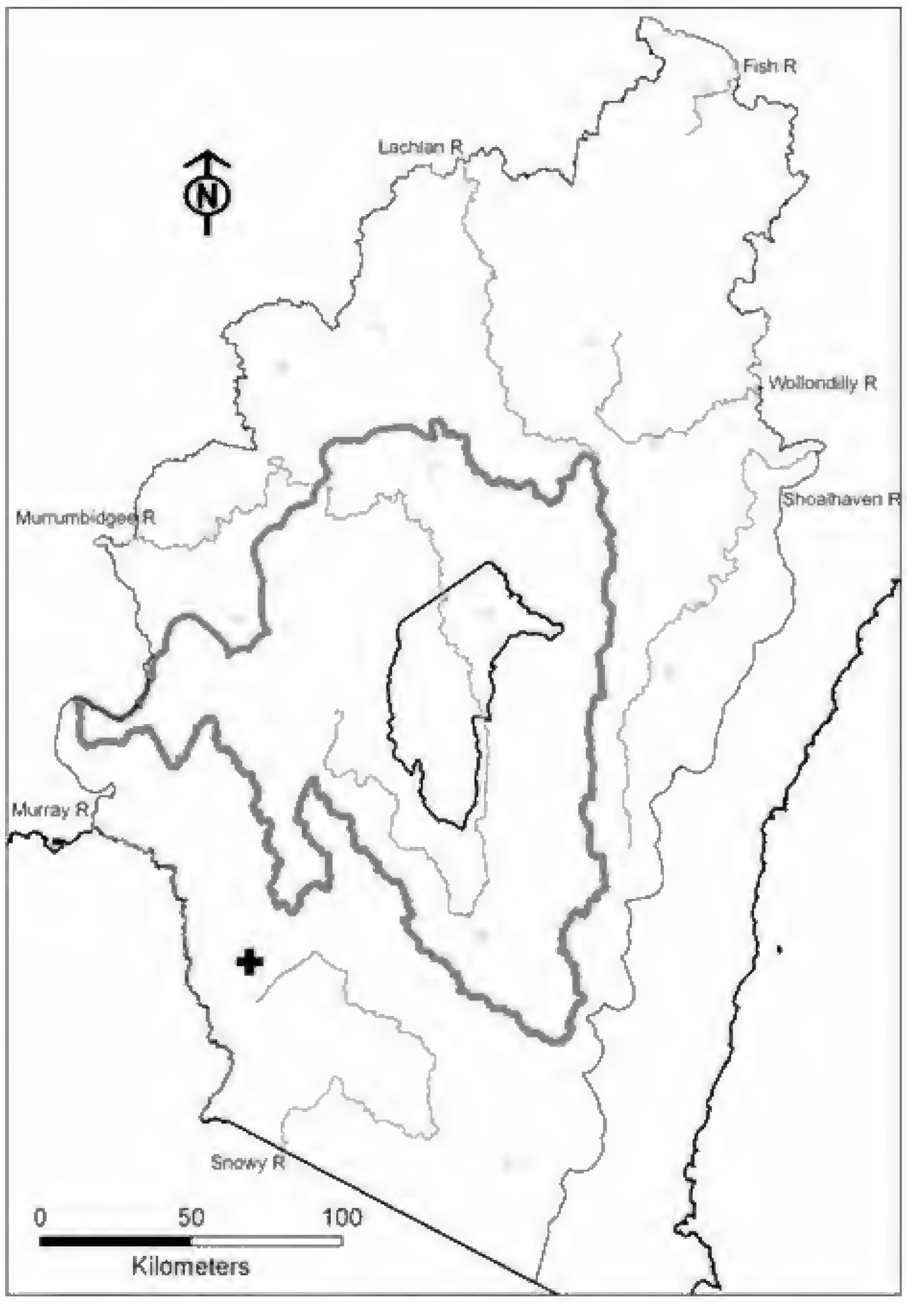

Fig. g172: Distribution of field samples assigned to this community.

Formation: Wet Sclerophyll Forests

Class: Montane Wet Sclerophyll Forests

u40: Alpine Ash very tall wet sclerophyll open forest primarily of the Australian Alps bioregion

Scientific Name: *Eucalyptus delegatensis* ± *Eucalyptus dalrympleana / Polyscias sambucifolia* subsp. *leptophylla – Coprosma hirtella – Veronica derwentiana / Poa helmsii – Stellaria pungens – Polystichum proliferum*

Number of samples:	35
Richness [mean (±SD)]:	27 (7)
Slope (degrees):	(1) 16–26 (35)
Altitude (m asl):	(1021) 1163–1337 (1504)
Ave. Annual Rainfall (mm):	(1042) 1261–1533 (1802)
Temp. Annual Range (°C):	(22.1) 23.2–24.6 (25.2)

Vegetation Description: Community u40 is a very tall open forest dominated by *Eucalyptus delegatensis*, often with *Eucalyptus dalrympleana* occurring at low abundance. At maturity, this community ranges from 25m to 45m in height. The understorey is predominantly shrubby and of variable density depending on site condition and time since fire. It is typically dominated by *Polyscias sambucifolia* subsp. *leptophylla*, *Tasmannia xerophila* and *Coprosma hirtella. Daviesia latifolia* and *Acacia obliquinervia* occur in many sites in abundance after fire. *Polystichum proliferum*, *Veronica derwentiana*, *Dianella tasmanica, Stellaria pungens*, *Viola betonicifolia* and *Poa helmsii* are frequently occurring groundlayer taxa.

This community is found mainly from Cabramurra to The Pilot on the western side of the Kosciuszko Range, mostly on steep slopes. In the ACT, it is found in Namadgi NP at Bulls Head and above Smokers Gap. At higher altitudes the community may grade into Community u158 [*Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion*], and at lower elevations it may grade into Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*].

Eucalyptus delegatensis is killed by crown fires. Recruitment after hot fires is often prolific, with very high stand densities. Following a crown fire the vegetation is often dominated by shrubs of the genera *Daviesia* and *Acacia* for several years until trees grow sufficiently to exert site dominance. The vegetation is often extremely dense, with many thousands of tree stems per hectare. If fires occur at intervals of 20 years or less, young *Eucalyptus delegatensis* are unlikely to have flowered and developed seed. In these circumstances the vegetation may become a shrubland with scattered trees of *Eucalyptus dalrympleana* or *Eucalyptus pauciflora* subsp. *pauciflora*, which usually resprout after fire (G. Robertson, OEH, pers. comm.), presenting a succession to Community u53 [*Mountain Gum – Blackwood tall wet sclerophyll open forest primarily on granitoids of the Australian Alps and western South Eastern Highlands bioregions*] or Community u239 [*Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia obliquinervia	2	37	1	3	P
Acaena novae-zelandiae	1	51	1	27	P
Asperula euryphylla	2	29	1	<1	P
Bossiaea foliosa	2	29	2	4	P
Cassinia aculeata	2	46	1	14	P
Coprosma hirtella	2	86	1	11	P
Daviesia latifolia	4	57	2	7	P
Dianella tasmanica	2	71	1	16	P
Eucalyptus dalrympleana	1	46	3	20	P
Eucalyptus delegatensis	3	91	3	4	P
Galium polyanthum	2	23	1	2	P
Leucopogon gelidus	1	26	1	2	P
Olearia megalophylla	2	31	1	4	P
Olearia phlogopappa	1	54	1	2	P
Ozothamnus secundiflorus	1	37	1	<1	P
Picris angustifolia	1	20	1	2	P
Poa ensiformis	3	23	2	2	P
Poa helmsii	3	80	1	3	P
Polyscias sambucifolia subsp. *leptophylla*	2	89	1	4	P
Polystichum proliferum	2	80	1	7	P
Prostanthera lasianthos	1	31	1	1	P
Rubus parvifolius	2	71	1	11	P
Senecio pinnatifolius var. *lanceolatus*	2	37	2	<1	P
Stellaria pungens	2	83	2	31	P
Tasmannia xerophila	2	57	1	1	P
Veronica derwentiana	2	80	1	6	P
Viola betonicifolia	2	71	1	27	P
Viola hederacea	1	40	2	18	P
Clematis aristata	1	43	1	24	C

Threatened communities: Nil

Equivalent vegetation types: This community is defined by a large group of field survey plots, some of which (10) were also classified by Gellie (2005). Most of these were assigned to Community VG87 [*Western Escarpment Moist Shrub/Herb/Grass Forest*], with a smaller number classified as Community VG86 [*Western Sub-alpine Moist Shrub Forest*].

Frequently occurring weeds: The distribution of this community on public land is the primary reason for the low abundance of weed species within it. Disturbances most likely to allow weed invasion include logging (in State Forests), road construction and maintenance, and high intensity fire. *Cirsium vulgare* (0.17) was the most commonly recorded weed species from within this community.

Threats: Hot fires at intervals of less than 20 years are likely to eliminate the key canopy species, *Eucalyptus delegatensis*.

Reservation status: There are around 100,000 hectares of *Eucalyptus delegatensis* (all community types) in NSW, with about 80,000 hectares reserved in Kosciuszko NP and Brindabella NP (G. Robertson, OEH, pers. comm.).Most of the area not reserved occurs in Bago, Maragle and Ingebyra SFs..

Extent of clearing: This community has not been affected by clearing, although it is the subject of regenerative logging in State Forest tenure.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u40: A burnt example of community u40, with a regenerating *Daviesia latifolia* understorey on the Alpine Way between Tom Groggin and Dead Horse Gap, Kosciuszko NP.

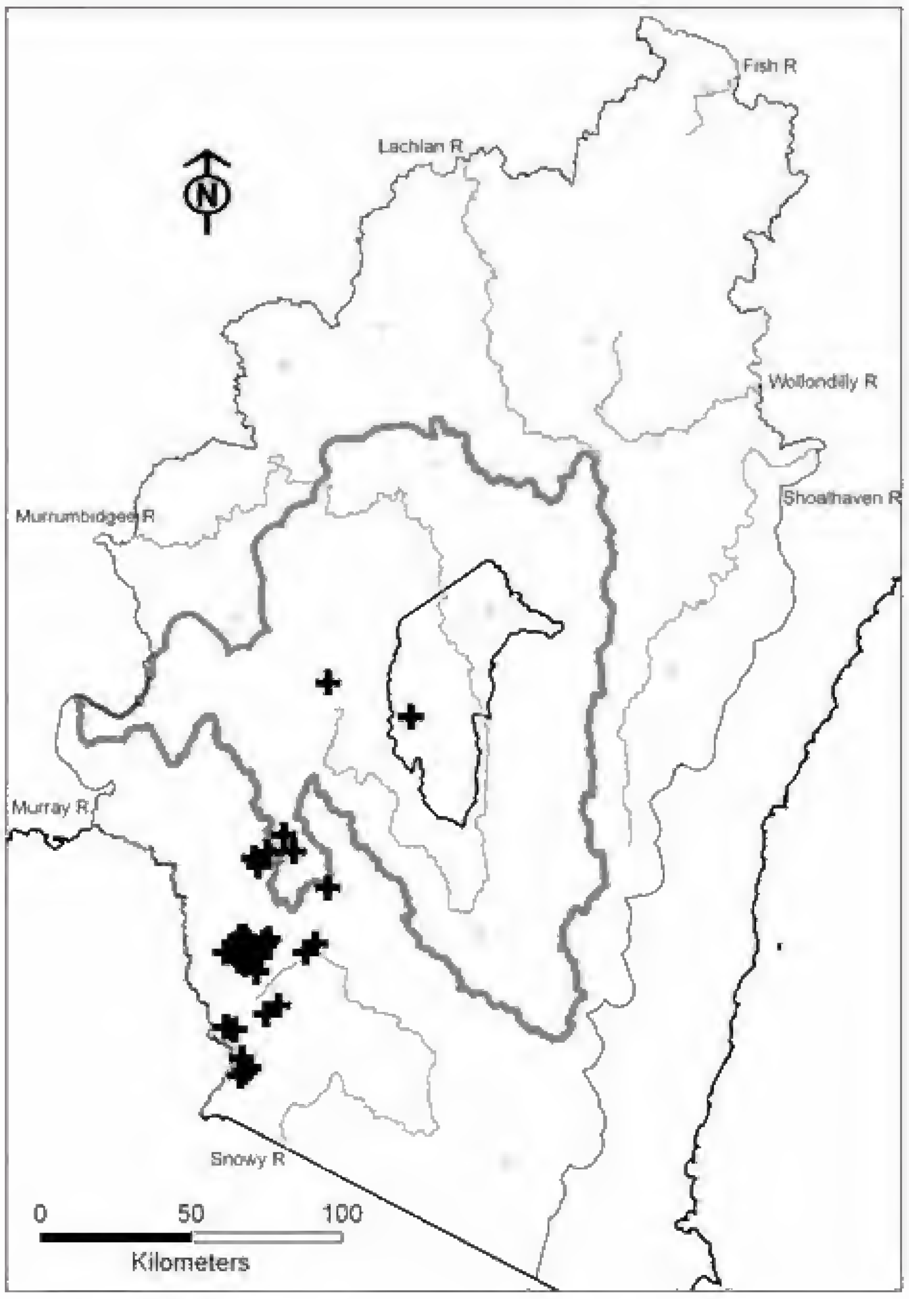

Fig. u40: Distribution of field samples assigned to this community.

u53: Mountain Gum – Blackwood tall wet sclerophyll open forest primarily on granitoids of the Australian Alps and western South Eastern Highlands bioregions

Scientific Name: *Eucalyptus dalrympleana* ± *Eucalyptus delegatensis* – *Eucalyptus viminalis* – *Eucalyptus pauciflora* subsp. *pauciflora* / *Acacia melanoxylon* / *Leptospermum grandifolium* – *Epacris breviflora* – *Tasmannia lanceolata* / *Polystichum proliferum* – *Acaena novae–zelandiae* – *Blechnum nudum*

Number of samples: 18
Richness [mean (±SD)]: 34 (12)
Slope (degrees): (1) 8–18 (26)
Altitude (m asl): (924) 1101–1261 (1368)
Ave. Annual Rainfall (mm): (895) 1020–1385 (1506)
Temp. Annual Range (°C): (23.3) 23.9–25.3 (25.7)

Vegetation Description: Community u53 is a tall to very tall open forest dominated by *Eucalyptus dalrympleana.* The well developed midstorey is characterised by the tall shrub *Acacia melanoxylon* along with smaller shrubs such as *Leptospermum grandifolium*, *Coprosma hirtella*, *Tasmannia lanceolata*, *Coprosma quadrifida*, *Baeckea utilis* and *Lomatia myricoides.* The moist groundlayer is a diverse mix of ferns, forbs and grasses, including *Acaena novae-zelandiae*, *Polystichum proliferum*, *Blechnum nudum*, *Carex appressa*, *Poa helmsii*, *Blechnum penna-marina* subsp. *alpina*, *Clematis aristata*, *Mentha laxiflora*, *Lagenophora stipitata*, *Stellaria pungens*, *Pteridium esculentum*, *Viola hederacea* and *Asperula scoparia*.

This community is most common within northern parts of the Australian Alps bioregion, and adjacent high altitude regions of the western South Eastern Highlands bioregion. It is found through Namadgi NP, northern Kosciuszko NP and Bago SF. It occurs on a variety of aspects, but favours sheltered locations – most often adjacent to drainage features. It is most common on granite, granodiorite or metasedimentary geologies. Co-occurring communities include Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*] and Community u239 [*Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions*] which generally occupies more exposed locations. Narrow creeklines within Community u53 may be dominated by dense patches of *Leptospermum grandifolium*, a shrub of up to 4 metres in height.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia melanoxylon	2	67	1	14	P
Acaena novae-zelandiae	2	72	1	27	P
Baeckea utilis	2	44	2	1	P
Blechnum minus	2	39	1	<1	P
Blechnum nudum	3	67	2	3	P
Blechnum penna-marina subsp. *alpina*	2	61	1	<1	P
Blechnum wattsii	2	28	2	<1	P
Carex appressa	2	67	1	7	P
Clematis aristata	1	61	1	24	P
Coprosma hirtella	1	72	1	11	P
Coprosma quadrifida	1	50	1	8	P
Deyeuxia brachyathera	1	28	1	<1	P
Epacris breviflora	2	83	1	2	P
Epilobium billardierianum subsp. *hydrophilum*	2	44	1	<1	P
Eucalyptus dalrympleana	2	61	3	20	P
Eucalyptus delegatensis	3	39	3	5	P
Eucalyptus viminalis	3	39	3	13	P
Gonocarpus micranthus	1	22	1	2	P
Gratiola peruviana	2	22	1	1	P
Isolepis subtilissima	1	33	1	<1	P
Lagenophora stipitata	2	56	1	17	P
Leptinella filicula	1	28	1	3	P
Leptospermum grandifolium	3	100	2	1	P
Lomatia myricoides	2	44	1	11	P
Mentha laxiflora	2	61	2	<1	P
Olearia phlogopappa	2	33	1	3	P
Poa helmsii	2	67	2	3	P
Polyscias sambucifolia subsp. *leptophylla*	1	28	2	4	P
Polystichum proliferum	2	72	1	7	P
Prostanthera lasianthos	3	22	1	1	P
Ranunculus lappaceus	1	39	1	11	P
Rubus parvifolius	2	56	1	11	P
Senecio biserratus	1	22	1	<1	P
Senecio hispidulus	2	22	1	2	P
Tasmannia lanceolata	2	72	1	3	P
Veronica derwentiana	1	39	1	7	P
Pteridium esculentum	1	44	2	27	C
Stellaria pungens	1	50	2	31	C
Viola hederacea	1	44	2	18	C

Threatened communities: Nil.

Equivalent vegetation types: This community is most closely related to Community VG86 [*Western Sub-alpine Moist Shrub Forest*] described by Gellie (2005). Patches where *Leptospermum grandifolium* is dominant may represent VG84 [*Montane Wet Heath/Herb Woodland*] of Gellie (2005) but this wasn't identified as a distinct community in the current study, possibly because of undersampling. A *Leptospermum grandifolium* shrubland occurs in similar vegetation and landscape positions in the Victorian high country.

Frequently occurring weeds: The weeds most frequently recorded in this community are typical of those recorded in other wet forest communities of the region, and include *Cirsium vulgare* (0.22), *Hypochaeris radicata* (0.28) and *Prunella vulgaris* (0.33).

Threats: Where this community occurs in State Forest or on private land, impacts associated with logging are a potential threat to the overstorey and structure of the understorey. Grazing by feral herbivores may also impact upon this community, especially where it occurs within drainage features or adjacent to open woodland communities. As with all vegetation in extensively forested regions, frequent and intense fire represents a major threat to the distribution and composition of this community.

Reservation status: Recorded from survey plots within Kosciuszko NP and Namadgi NP; likely to be well reserved.

Extent of clearing: Considered minimal.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u53: Community u53 dominated by tall *Eucalyptus dalrympleana* with a shrubby herbaceous understorey. Murray's Gap Trail, Namadgi NP.

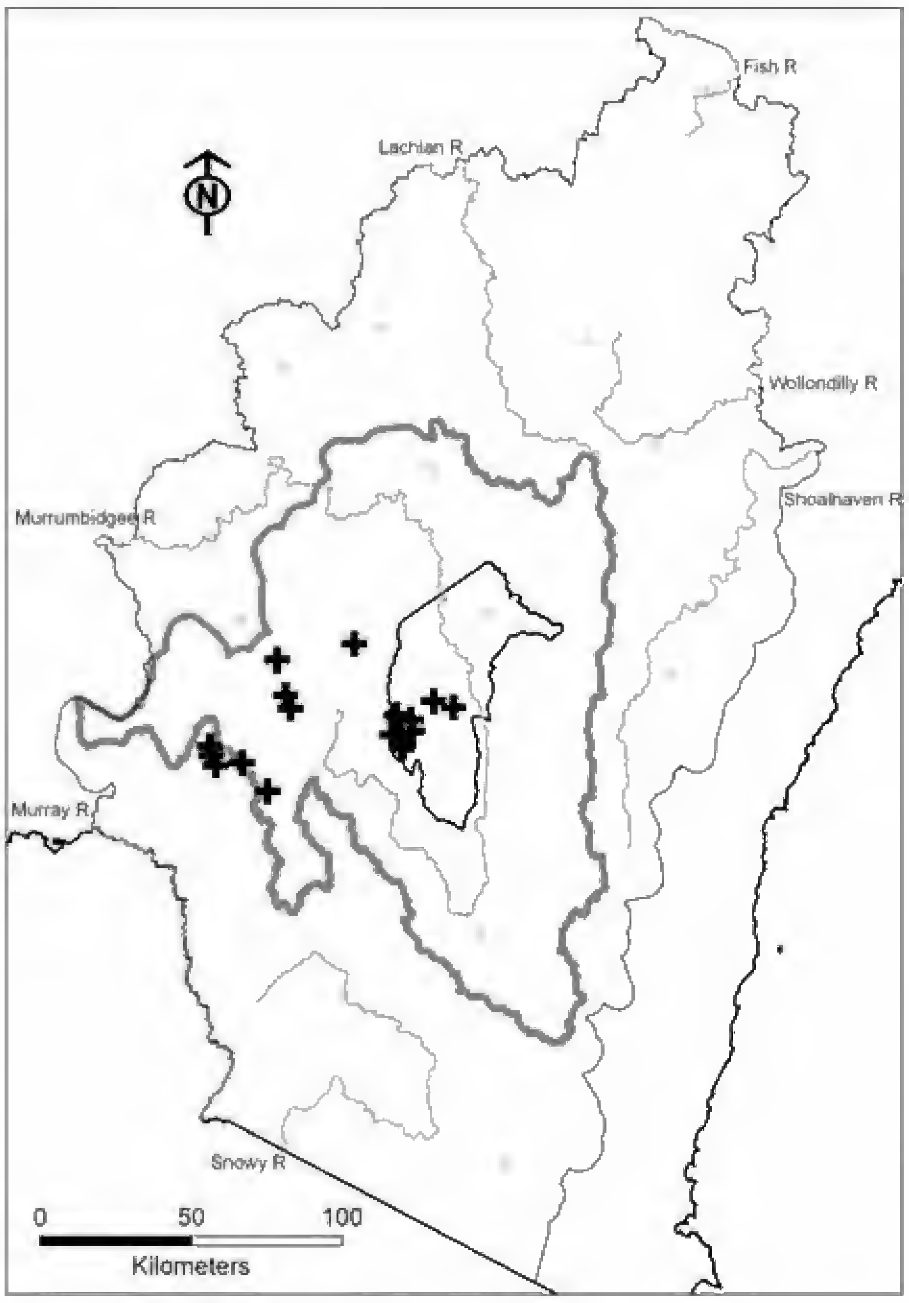

Fig. u53: Distribution of field samples assigned to this community.

u239: Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions

Scientific Name: *Eucalyptus delegatensis – Eucalyptus dalrympleana* ± *Eucalyptus pauciflora* subsp. *pauciflora / Coprosma hirtella – Lomatia myricoides – Olearia megalophylla / Asperula scoparia – Clematis aristata – Stellaria pungens – Viola betonicifolia*

Number of samples:	100
Richness [mean (±SD)]:	29 (7)
Slope (degrees):	(1) 8–18 (36)
Altitude (m asl):	(1006) 1179–1357 (1526)
Ave. Annual Rainfall (mm):	(846) 1101–1365 (1653)
Temp. Annual Range (°C):	(22.2) 23.5–24.5 (25.3)

Vegetation Description: Community u239 is a tall to very tall open forest dominated by *Eucalyptus delegatensis* and *Eucalyptus dalrympleana*. *Eucalyptus pauciflora* subsp. *pauciflora* is often present. The higher abundance of *Eucalyptus dalrympleana* and the presence of *Eucalyptus pauciflora* subsp. *pauciflora* and other species of drier sites indicate that this community occurs in drier habitats than Community u40 [*Alpine Ash tall wet sclerophyll open forest primarily of the Australian Alps bioregion*]. At maturity, this community ranges from 25m to 45m in height. Below the canopy it is often variable and may be grassy or shrubby, depending on site condition and fire history. The shrub layer is often a sparse cover of *Coprosma hirtella*, *Acacia dealbata*, *Daviesia mimosoides* and *Lomatia myricoides*. The groundlayer is a mixture of grasses, forbs and climbers (e.g. *Poa sieberiana*, *Poa phillipsiana*, *Asperula scoparia*, *Stellaria pungens*, *Clematis aristata*, *Coronidium scorpiodes* and *Viola betonicifolia*).

This community is found mainly from the Brindabella Range south to the Victorian border, but is more common north of Khancoban, mostly on steep slopes between 1,000 and 1,400 metres above sea level. In the Australian Alps bioregion it often grades into Community u158 [*Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion*], and at lower elevations this community grades into Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*]. In moister sheltered slopes at the southern edge of its range this community may grade into Community u40 [*Alpine Ash tall wet sclerophyll open forest primarily of the Australian Alps bioregion*].

For information on the fire ecology of *Eucalyptus delegatensis* dominated communites, refer to the description of Community u40.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	2	51	2	25	P
Acacia kettlewelliae	2	5	1	<1	P
Acacia obliquinervia	2	23	1	2	P
Acaena novae-zelandiae	1	45	1	27	P
Arthropodium milleflorum	1	34	1	7	P
Asperula scoparia	2	85	2	20	P
Billardiera macrantha	1	6	1	<1	P
Brachyscome spathulata	2	38	1	10	P
Caladenia alpina	1	5	1	<1	P
Cassinia aculeata	1	39	1	13	P
Chiloglottis pluricallata	1	7	1	<1	P
Chiloglottis valida	1	14	1	2	P
Clematis aristata	2	78	1	22	P
Coprosma hirtella	2	85	1	9	P
Coronidium scorpioides	2	49	1	19	P
Craspedia jamesii	1	20	1	3	P

Craspedia spp.	2	19	1	3	P
Daviesia latifolia	3	26	2	6	P
Daviesia mimosoides subsp. *mimosoides*	3	36	2	9	P
Daviesia ulicifolia	2	32	1	9	P
Deyeuxia monticola	1	22	1	5	P
Deyeuxia rodwayi	1	5	1	1	P
Dianella tasmanica	1	48	1	15	P
Eucalyptus dalrympleana	2	77	3	18	P
Eucalyptus delegatensis	4	96	3	2	P
Eucalyptus pauciflora subsp. *pauciflora*	2	50	3	20	P
Geranium potentilloides	1	43	1	12	P
Gonocarpus montanus	1	8	1	1	P
Lagenophora stipitata	1	40	1	17	P
Leptinella filicula	1	17	1	3	P
Leucopogon gelidus	1	15	1	2	P
Lobelia pedunculata	1	18	1	5	P
Lobelia puberula	1	11	1	<1	P
Lomatia myricoides	2	46	1	11	P
Olearia erubescens	1	45	1	11	P
Olearia megalophylla	1	45	1	4	P
Olearia phlogopappa	1	16	1	3	P
Oxylobium ellipticum	2	11	1	4	P
Ozothamnus stirlingii	2	9	1	<1	P
Ozothamnus thyrsoideus	1	8	1	2	P
Persoonia chamaepeuce	1	22	1	11	P
Persoonia subvelutina	2	20	1	<1	P
Picris angustifolia	1	10	1	2	P
Picris angustifolia subsp. *angustifolia*	2	7	1	2	P
Platylobium montanum	2	29	2	10	P
Poa helmsii	1	13	2	3	P
Poa induta	2	14	3	6	P
Poa phillipsiana	4	26	2	2	P
Podolobium alpestre	1	9	2	2	P
Polyscias sambucifolia subsp. *leptophylla*	2	36	2	3	P
Polystichum proliferum	1	19	1	7	P
Poranthera microphylla	1	60	1	26	P
Pterostylis monticola	1	7	1	<1	P
Ranunculus plebeius	1	14	1	3	P
Ranunculus scapiger	1	11	1	1	P
Ranunculus spp.	1	8	1	2	P
Senecio diaschides	1	15	1	5	P
Senecio gunnii	1	44	1	8	P
Senecio linearifolius	1	13	1	5	P
Stackhousia monogyna	1	23	1	12	P
Stellaria pungens	2	78	2	30	P
Tasmannia lanceolata	1	27	1	3	P
Veronica derwentiana	1	46	1	6	P
Viola betonicifolia	1	74	1	26	P
Viola hederacea	1	31	2	18	P
Wahlenbergia gloriosa	1	23	1	2	P
Lomandra longifolia	2	51	2	42	C
Poa sieberiana	3	51	2	48	C

Threatened communities: Nil

Equivalent vegetation types: This community is defined by a very large group of field survey plots, some of which (22) were also classified by Gellie (2005). These were assigned to a wide variety of Forest Ecosystems and there is no direct equivalent – related types include Community VG102 [*Brindabella Montane Dry Fern/Grass Forest*] and Community VG86 [*Western Sub-alpine Moist Shrub Forest*].

Frequently occurring weeds: Weeds are generally uncommon in this community, most likely because it is remote from major anthropogenic disturbances. Weed species that were recorded in this community are typical of other wet forest communities and include *Hypochaeris radicata* (0.42) and *Crepis capillaris* (0.15), although both are generally found in low numbers.

Plate u239: Community u239 with an open shrub layer. Alpine Creek Fire Trail, northern Kosciuszko NP.

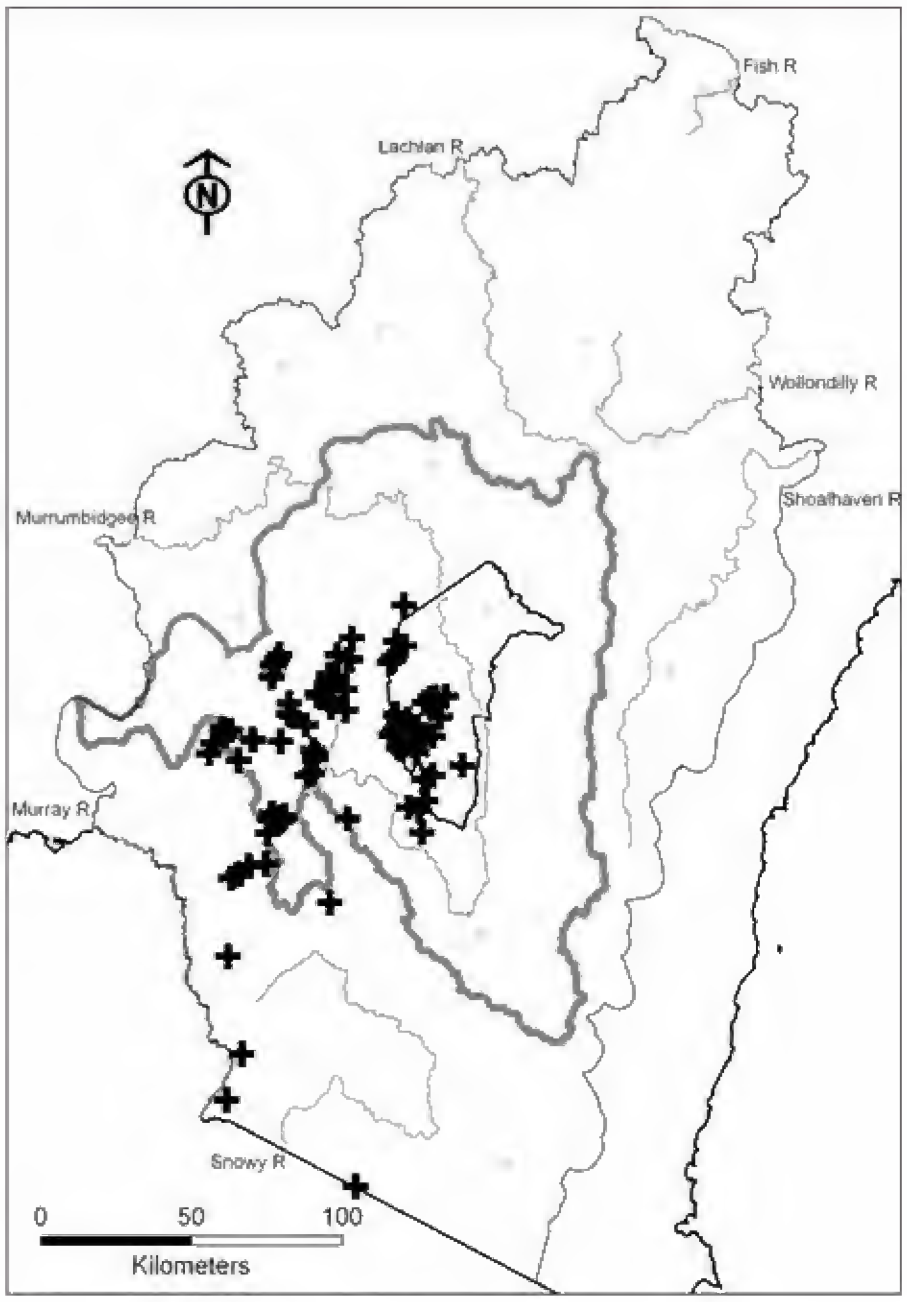

Fig. u239: Distribution of field samples assigned to this community.

Threats: The greatest threat to this community is the combined effect of high fire intensity and frequency. Because *Eucalyptus delegatensis* is an obligate seeder (Vivian & Cary 2012), hot fires at intervals of less than 20 years have the potential to eliminate the species (G. Robertson, OEH, pers. comm.).

Reservation status: There are around 100,000 hectares of *Eucalyptus delegatensis* (all community types) in NSW, with about 80,000 hectares being reserved in Kosciuszko NP and Brindabella NP. Most of the area not reserved occurs in Bago, Maragle and Ingebyra SFs (G. Robertson, OEH, pers. comm.).

Extent of clearing: This community has not been affected by clearing.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Vivian, L.M. & Cary, G.J. (2012) Relationship between leaf traits and fire-response strategies in shrub species of a mountainous region of south-eastern Australia. *Annals of Botany* 109: 197–208.

Class: Southern Tableland Wet Sclerophyll Forests

u52: Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and the northern Australian Alps bioregions

Scientific Name: *Eucalyptus viminalis – Eucalyptus radiata* subsp. *robertsonii / Acacia melanoxylon / Rubus parvifolius – Cassinia aculeata / Pteridium esculentum – Clematis aristata – Stellaria pungens*

Number of samples:	85
Richness [mean (±SD)]:	36 (9)
Slope (degrees):	(2) 12–21 (36)
Altitude (m asl):	(426) 804–1088 (1249)
Ave. Annual Rainfall (mm):	(739) 1001–1189 (1396)
Temp. Annual Range (°C):	(24) 24.7–25.7 (28.2)

Vegetation Description: Community u52 is a very tall eucalypt forest dominated by *Eucalyptus viminalis* and *Eucalyptus radiata* subsp. *robertsonii*. *Eucalyptus fastigata* may be dominant in patches, which in the ACT can be found up to 1,320m above sea level (M. Kitchin, ACT ESDD, pers. comm.). The shrub layer of this community is open and variable in height, typically including *Acacia melanoxylon*, *Acacia dealbata*, *Cassinia aculeata*, *Lomatia myricoides* and *Coprosma quadrifida*. The moist groundlayer is a mix of forbs, ferns, climbers and grasses including *Pteridium esculentum*, *Clematis aristata*, *Stellaria pungens*, *Acaena novae–zelandiae*, *Lagenophora stipitata*, *Viola hederacea*, *Rubus parvifolius*, *Glycine clandestina*, *Asperula scoparia*, *Microlaena stipoides*, *Poa sieberiana*, *Geranium potentilloides* and *Hydrocotyle laxiflora*.

This community is prevalent in Namadgi and Brindabella NPs, but extends east to Tinderry NR, and west through Kosciuszko NP to Bondo SF near Tumut. It occupies a variety of aspects, but is most common in sheltered environments. It occurs on a variety of geologies, including rhyolite, granite, granodiorite and meta-sediments. Associated communities are moist forests and subalpine woodlands of the Australian Alps and western South Eastern Highlands bioregions. These include Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*] which occurs at higher altitude, Community u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*] on drier and more exposed sites, and Community u152 [*Robertson's Peppermint – Red Stringybark very tall grass-forb sheltered open forest of the southwest South Eastern Highlands and upper South Western Slopes bioregions*] also on drier sites.

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia dealbata	2	65	2	25	P
Acacia melanoxylon	2	68	1	12	P
Acaena novae-zelandiae	1	81	1	26	P
Adiantum aethiopicum	1	21	2	3	P
Asperula scoparia	1	65	2	21	P
Asplenium flabellifolium	1	25	1	8	P
Australina pusilla	1	12	2	1	P
Bedfordia arborescens	1	13	3	2	P
Blechnum minus	1	21	1	<1	P
Blechnum nudum	2	19	2	3	P
Bursaria spinosa	2	21	1	10	P
Carex appressa	2	29	1	6	P
Cassinia aculeata	1	69	1	12	P
Clematis aristata	1	87	1	22	P
Coprosma hirtella	1	46	1	11	P
Coprosma quadrifida	1	47	1	7	P
Cynoglossum australe	1	12	1	4	P
Deyeuxia rodwayi	2	9	1	<1	P
Dianella tasmanica	1	45	1	16	P
Dichondra repens	1	54	2	20	P
Drymophila cyanocarpa	1	7	1	<1	P
Echinopogon ovatus	1	46	1	9	P
Epilobium billardierianum subsp. *cinereum*	1	16	1	5	P
Eucalyptus fastigata	4	21	3	6	P
Eucalyptus radiata subsp. *robertsonii*	3	56	3	8	P
Eucalyptus viminalis	3	73	3	11	P
Euchiton japonicus	1	36	1	14	P
Galium gaudichaudii	1	22	1	9	P
Galium polyanthum	1	11	1	2	P
Geranium potentilloides	1	61	1	12	P
Glycine clandestina	1	69	1	29	P
Gratiola peruviana	1	18	1	1	P
Gynatrix pulchella	1	16	2	<1	P
Hydrocotyle laxiflora	1	59	2	29	P
Lagenophora stipitata	1	79	1	16	P
Leptinella filicula	1	15	1	3	P
Leptospermum juniperinum	1	7	2	<1	P
Lobelia pedunculata	1	14	1	5	P
Lomatia myricoides	1	60	1	10	P
Luzula flaccida	1	26	1	13	P
Mentha diemenica	1	18	1	2	P
Microlaena stipoides	1	65	2	33	P
Olearia argophylla	1	8	2	2	P
Olearia erubescens	1	25	1	12	P
Olearia megalophylla	1	20	1	4	P
Olearia stellulata	1	13	1	2	P
Platylobium montanum	1	29	2	10	P
Poa helmsii	1	25	2	3	P
Poa tenera	3	11	2	2	P
Polystichum proliferum	1	55	1	6	P
Pomaderris aspera	2	27	2	2	P
Prostanthera lasianthos	1	7	1	1	P
Pteridium esculentum	3	89	2	25	P
Pterostylis coccina	1	12	1	<1	P
Pterostylis decurva	1	7	1	<1	P
Ranunculus lappaceus	1	46	1	10	P
Ranunculus plebeius	1	13	1	3	P
Rubus parvifolius	1	71	1	10	P
Senecio diaschides	1	28	1	5	P
Senecio linearifolius	1	29	1	4	P
Stellaria pungens	1	85	2	30	P

Plate u52: Community u52 dominated by *Eucalyptus viminalis* and *Eucalyptus radiata* subsp. *robertsonii* with scattered shrubs and a grassy understorey. Lower south-western slope of Mt. Tennent, Tennent Fire Trail, Namadgi NP.

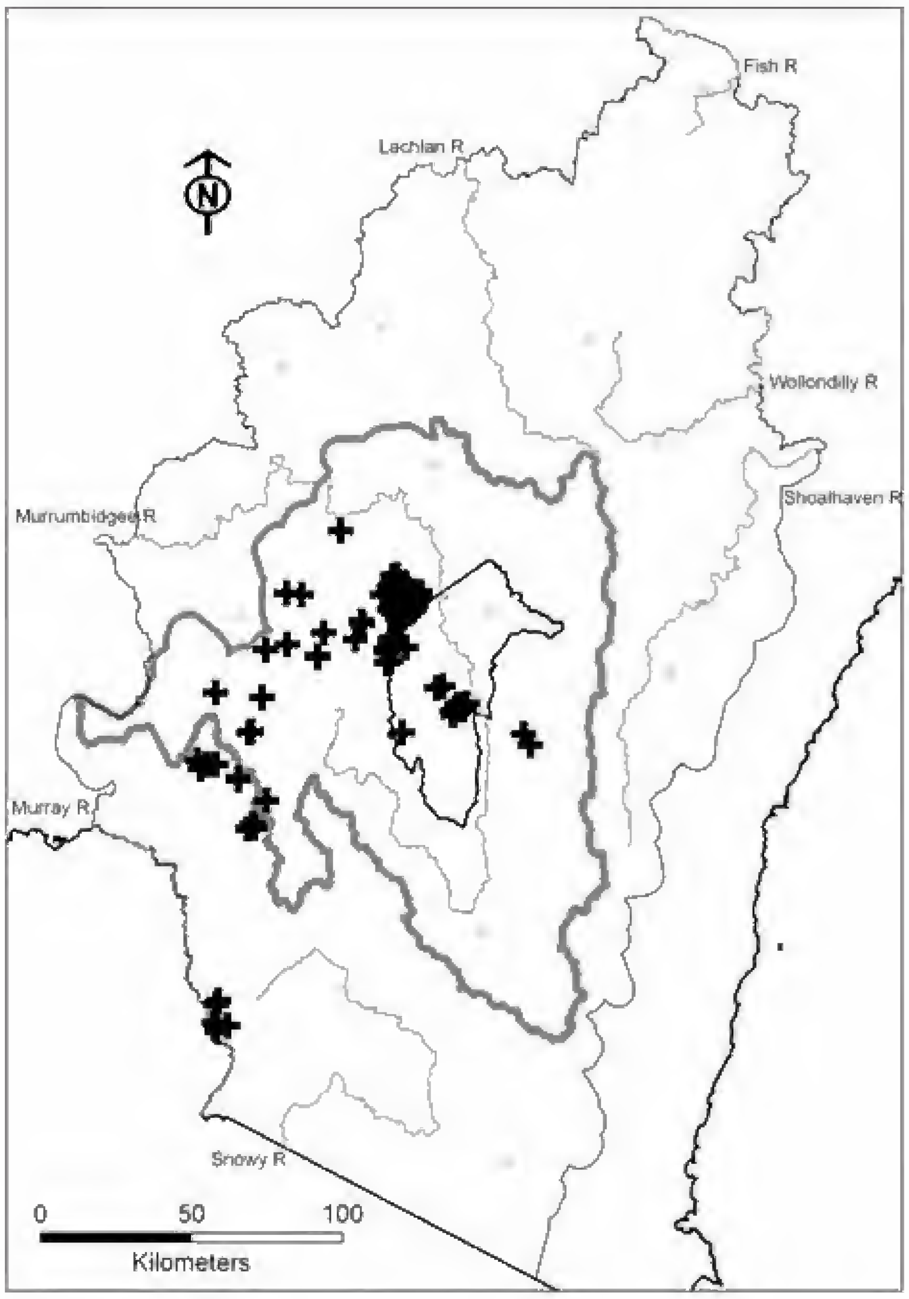

Fig. u52: Distribution of field samples assigned to this community.

Urtica incisa	1	15	1	2	P
Veronica calycina	1	29	1	16	P
Veronica derwentiana	1	11	1	<1	P
Viola hederacea	1	73	2	17	P
Lomandra longifolia	1	48	2	42	C
Poa sieberiana	2	64	2	48	C

Threatened communities: Nil.

Equivalent vegetation types: Most similar to Community VCA 300 [*Ribbon Gum – Narrow-leaved (Robertson's) Peppermint montane fern-grass tall open forest on deep clay loam soils in the upper NSW SWS bioregion and western Kosciuszko escarpment*] (Benson *et al.* 2010) and represents a combination of Community VG82 [*Western Montane Acacia Fern/Herb Forest*], Community VG83 [*Montane Riparian Moist Shrub/Grass/Herb Forest*] and Community VG102 [*Brindabella Montane Dry Fern/Grass Forest*] (Gellie 2005).

Frequently occurring weeds: *Cirsium vulgare* (0.41) and *Rosa rubiginosa* (0.24) are the most frequently recorded weeds form this community. The prevalence of *Rosa rubiginosa*, in particular, suggests widespread past disturbance to the canopy and/or the shrub layer.

Threats: As with other forest communities, frequent and intense fire is a significant potential threat to this community. Due to the open nature of the understorey in this community, the other major risk factor is damage associated with feral herbivores.

Reservation status: Likely to be well reserved. Recorded from survey plots in Bimberi NR, Black Andrew NR, Brindabella NP and SCA, Kosciuszko NP, Namadgi NP and Tinderry NR.

Extent of clearing: Likely to be minor.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Class: Southern Escarpment Wet Sclerophyll Forests

p338: Brown Barrel wet sclerophyll very tall grass-herb open forest primarily of the Gourock and Tallaganda Ranges in the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus fastigata* ± *Eucalyptus radiata* subsp. *radiata – Eucalyptus viminalis / Acacia dealbata – Leucopogon lanceolatus / Pteridium esculentum / Poa meionectes – Dianella tasmanica – Viola hederacea – Stellaria pungens – Clematis aristata*

Number of samples:	112
Richness [mean (±SD)]:	33 (8)
Slope (degrees):	(0) 5–15 (33)
Altitude (m asl):	(562) 907–1117 (1353)
Ave. Annual Rainfall (mm):	(759) 911–1005 (1144)
Temp. Annual Range (°C):	(22.7) 23.7–24.7 (25.8)

Vegetation Description: Community p338 is a very tall eucalypt forest dominated by *Eucalyptus fastigata*, *Eucalyptus radiata* subsp. *radiata* and *Eucalyptus viminalis*. The shrub layer is variable in height depending on local dominance, but typically includes *Acacia dealbata*, *Leucopogon lanceolatus*, *Acacia melanoxylon*, *Coprosma quadrifida* and *Lomatia myricoides*. The moist groundlayer is a mix of ferns, forbs and grasses including *Pteridium esculentum*, *Poa meionectes*, *Dianella tasmanica*, *Viola hederacea*, *Stellaria pungens*, *Lagenophora stipitata*, *Poranthera microphylla*, *Gonocarpus tetragynus*, *Dichondra repens*, *Microlaena stipoides*, *Veronica calycina* and *Asperula scoparia*. The climber *Clematis aristata* is often present.

This community is generally confined to the western fall of the coastal escarpment within the South Eastern Highlands bioregion. It is common in sheltered environments typically on granite or meta-sedimentary geologies, but is also recorded from granodiorite and basalt substrates. Associated communities are dry forests of the Great Dividing Range including Community p8 [*Silvertop Ash – Narrow-leaved Peppermint shrubby tall dry open forest primarily on sedimentary ridges of the eastern South Eastern Highlands bioregion*] and Community e24 [*Mountain Gum – Snow Gum subalpine very tall dry shrubby open forest primarily in the Kybeyan – Gourock subregion of the South Eastern Highlands bioregion*], which both occur in more exposed locations. In the ACT and west into the Brindabellas, *Eucalyptus fastigata* stands are considered part of Community u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and northern Australian Alps bioregions*] rather than Community p338.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	2	61	2	25	P
Acacia melanoxylon	1	36	1	13	P
Acaena novae-zelandiae	2	54	1	27	P
Acrothamnus hookeri	2	20	1	7	P
Acrotriche divaricata	2	9	1	<1	P
Ajuga australis	1	17	1	7	P
Asperula scoparia	2	56	2	21	P
Blechnum cartilagineum	1	5	2	1	P
Brachyscome formosa	2	4	2	<1	P
Chiloglottis pluricallata	1	13	1	<1	P
Chiloglottis spp.	1	10	2	1	P
Choretrum candollei	1	4	1	<1	P
Clematis aristata	1	72	1	22	P
Clematis spp.	2	6	2	<1	P
Comesperma volubile	1	7	1	1	P
Coprosma quadrifida	1	37	1	7	P
Coronidium scorpioides	2	54	1	19	P
Cyathea australis	1	10	2	2	P
Desmodium gunnii	2	7	2	1	P
Dianella tasmanica	2	82	1	14	P
Dichondra repens	2	57	2	19	P
Drymophila cyanocarpa	2	5	1	<1	P
Echinopogon ovatus	1	23	1	10	P
Eucalyptus cypellocarpa	2	13	3	5	P
Eucalyptus fastigata	3	70	3	4	P
Eucalyptus nitens	3	8	3	<1	P
Eucalyptus obliqua	3	17	3	3	P
Eucalyptus radiata subsp. *radiata*	2	48	3	10	P
Eucalyptus viminalis	3	43	3	12	P
Galium leiocarpum	1	15	1	4	P
Geranium potentilloides	2	32	1	12	P
Glycine clandestina	2	61	1	29	P
Goodia lotifolia	1	8	1	1	P
Hakea eriantha	1	20	1	1	P
Helichrysum leucopsideum	1	6	1	<1	P
Hydrocotyle acutiloba	2	7	1	2	P
Lagenophora stipitata	2	71	1	15	P
Leptinella filicula	2	17	1	3	P
Leucopogon lanceolatus	2	56	2	11	P
Lobelia puberula	1	9	1	<1	P
Lomandra longifolia	2	68	2	41	P
Lomatia fraseri	2	12	1	1	P
Lomatia myricoides	2	27	1	11	P
Luzula flaccida	1	24	1	13	P
Microlaena stipoides	1	57	2	33	P
Olearia megalophylla	1	12	1	5	P
Persoonia silvatica	1	23	1	2	P
Plantago debilis	2	12	2	4	P
Poa ensiformis	2	7	2	2	P
Poa meionectes	3	87	2	14	P
Polyscias sambucifolia subsp. *sambucifolia*	2	11	1	1	P
Polystichum proliferum	1	17	1	7	P
Poranthera microphylla	1	66	1	26	P
Pteridium esculentum	3	89	2	25	P
Ranunculus pimpinellifolius	2	5	1	1	P
Rubus parvifolius	1	28	1	11	P
Schelhammera undulata	2	4	2	<1	P
Senecio prenanthoides	1	55	1	18	P
Smilax australis	2	21	2	2	P
Stellaria pungens	2	73	2	30	P
Tasmannia lanceolata	1	17	1	3	P
Veronica calycina	1	57	1	15	P
Viola hederacea	2	81	2	16	P
Xerochrysum bracteatum	1	17	1	1	P
Gonocarpus tetragynus	1	57	2	47	C

Threatened communities: Nil.

Equivalent vegetation types: Community WSFp338 [*Southern Range Wet Forest*] (Tozer *et al.* 2010) and a combination of Community VG55 [*Eastern Tableland Fern/Herb/Grass Moist Forest*], Community VG56 [*Tableland and Escarpment Moist Herb/Gern/Grass Forest*] and Community VG95 [*Tableland Acacia Moist Herb Forest*] (Gellie 2005).

Frequently occurring weeds: Compared with many communities, this community is relatively undisturbed and consequently weed species are uncommon. Nonetheless the highly dispersable *Hypochaeris radicata* (0.74) is present at low abundances in the majority of sites.

Threats: Because large areas of this community occur in State Forest, logging and its associated impacts may alter species composition and vegetation condition. Frequent and intense fire also has the potential to impact upon this community.

Reservation status: Likely to be well reserved. Recorded from survey plots in Badja Swamps NR, Bondi Gulf NR, Coolumbooka NR, Deua NP, Gourock NP, Monga NP and SCA, Southeast Forest NP, Tallaganda NP, Tallaganda SCA and Wadbilliga NP.

Extent of clearing: Not assessed, but likely to be minor due to its generally steep mountainous habitat.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Plate p338: An example of Community p338 dominated by *Eucalyptus fastigata*, *Eucalyptus radiata* subsp. *radiata* and *Eucalyptus cypellocarpa*, with *Leucopogon lanceolata*, *Dianella tasmanica* and *Pteridium esculentum* in the understorey. Cattlemans Link Firetrail, South East Forests NP.

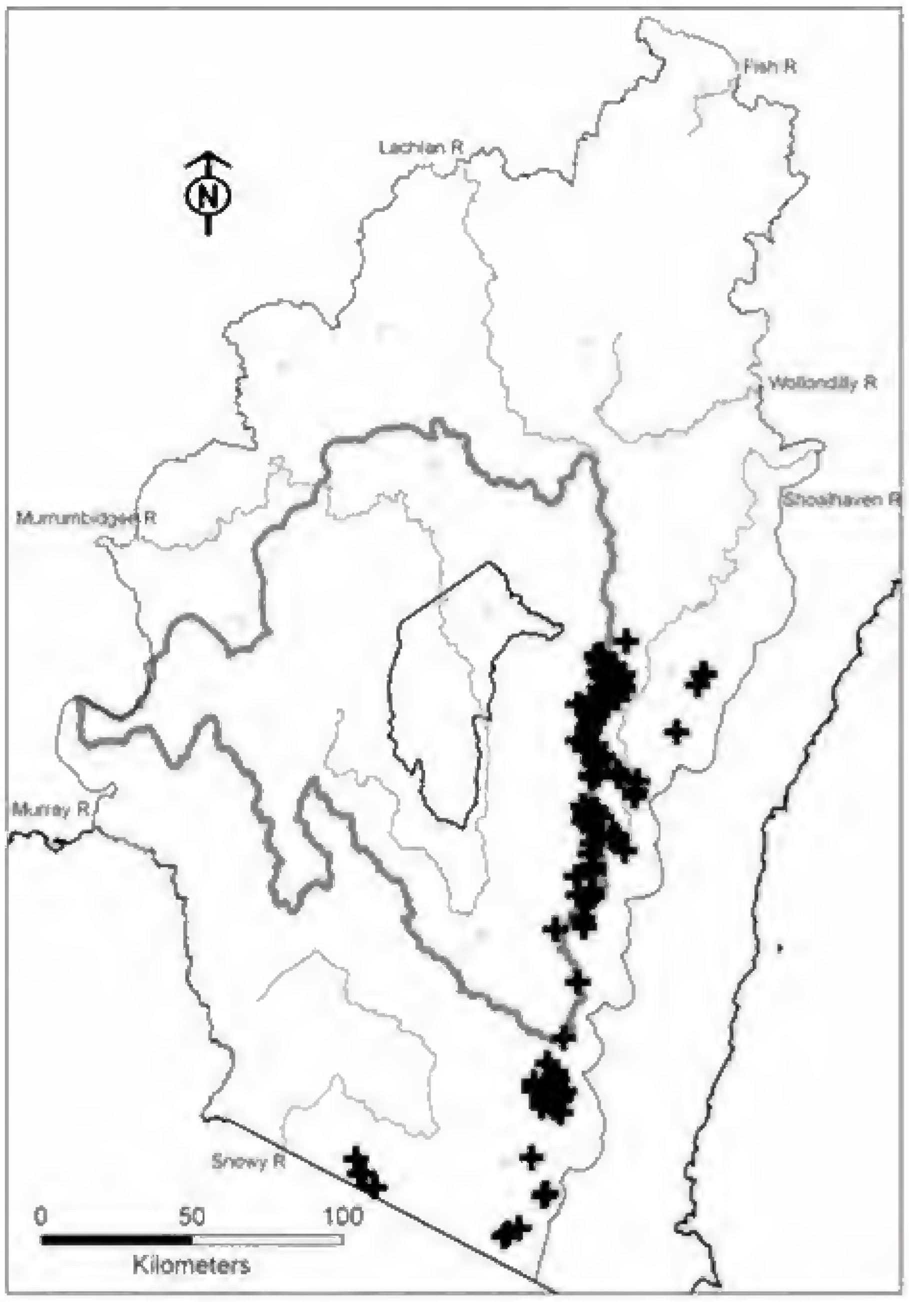

Fig. p338: Distribution of field samples assigned to this community

Formation: Dry Sclerophyll Forests

Class: Southern Tableland Dry Sclerophyll Forests

e24: Mountain Gum – Snow Gum very tall dry shrubby open forest primarily in the Kybeyan – Gourock subregion of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus dalrympleana – Eucalyptus pauciflora* subsp. *pauciflora – Eucalyptus radiata* **subsp**. *radiata / Persoonia silvatica – Monotoca scoparia / Lomandra longifolia – Poa meionectes – Stylidium graminifolium sens. lat. – Dianella tasmanica*

Number of samples:	30
Richness [mean (±SD)]:	25 (8)
Slope (degrees):	(0) 2–8 (21)
Altitude (m asl):	(758) 922–1147 (1351)
Ave. Annual Rainfall (mm):	(809) 879–1036 (1120)
Temp. Annual Range (°C):	(22.7) 23.5–24.2 (25.6)

Vegetation Description: Community e24 is a very tall dry shrubby open forest dominated by *Eucalyptus dalrympleana*, often with *Eucalyptus pauciflora* subsp. *pauciflora* or *Eucalyptus radiata* subsp. *radiata*. The shrub layer is generally patchy, with species such as *Persoonia silvatica*, *Bossiaea foliosa*, *Monotoca scoparia*, *Daviesia ulicifolia* and the tall shrubs *Acacia dealbata* and *Exocarpos strictus*. The groundlayer is usually sparse and dominated by leaf litter and woody debris, with patches of forbs including *Lomanda longifolia*, *Stylidium graminifolium sens. lat.*, *Dianella tasmanica* and *Gonocarpus tetragynus* and grasses including *Poa meionectes* and *Poa sieberiana*.

This community is distributed along the western fall of the Great Dividing Range from Tallaganda NP in the north and extending south to the Bombala area. It is generally found on loamy forest soils of low fertility. This community generally occurs in a mosaic with Community p338 [*Brown Barrel wet sclerophyll very tall grass-herb open forest primarily of the Gourock and Tallaganda Ranges in the South Eastern Highlands bioregion*] occurring on more sheltered aspects on better soils. It is often increasingly dominated by *Eucalyptus pauciflora* subsp. *pauciflora* at higher altitude within its range.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	**Fid**
Banksia marginata	2	30	1	3	P
Bossiaea foliosa	2	63	2	4	P
Choretrum pauciflorum	1	20	1	3	P
Daviesia ulicifolia	2	57	2	10	P
Dianella tasmanica	2	67	1	16	P
Eucalyptus dalrympleana	3	80	3	19	P
Eucalyptus pauciflora subsp. *pauciflora*	3	60	3	21	P
Eucalyptus radiata subsp. *radiata*	3	50	3	10	P
Exocarpos strictus	2	40	1	12	P
Gompholobium huegelii	1	27	1	5	P
Hovea linearis	1	47	1	13	P
Lomandra longifolia	2	80	2	42	P
Monotoca scoparia	2	60	1	14	P
Patersonia sericea var. *sericea*	2	27	2	3	P
Persoonia chamaepeuce	2	33	1	11	P
Persoonia silvatica	1	67	1	3	P

Poa meionectes	2	67	2	16	P
Polyscias sambucifolia subsp. *sambucifolia*	2	20	1	1	P
Stylidium graminifolium sens. lat.	2	70	1	25	P
Acacia dealbata	1	43	2	26	C
Coronidium scorpioides	2	40	1	20	C
Gonocarpus tetragynus	2	67	2	48	C
Hibbertia obtusifolia	1	40	1	35	C
Lomandra multiflora	1	40	1	18	C
Microlaena stipoides	1	57	2	34	C

Threatened communities: Components of this community may contain TSC Act 1995 – *Tablelands Snow Gum*, *Black Sallee*, *Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands*, *Sydney Basin*, *South East Corner and NSW South Western Slopes bioregions*.

Equivalent vegetation types: Community DSFe24 [*Subalpine Dry Shrub Forest*] (Tozer *et al.* 2010), with DSFe24 contains a moderate frequency of *Eucalypus dives* east of the study area. Some similarities with VG64 [*South East Tableland Edge Shrub/Grass Dry Forest*] (Gellie 2005).

Frequently occurring weeds: Weed species are uncommon throughout this community. The most commonly recorded species is *Hypochaeris radicata* (0.37), which is a highly disperable species often found at low abundance in extensively forested environments.

Threats: There are very few threats to the long-term structure and composition of this community, largely because it is well reserved and it has limited value to forestry (BRS & SFNSW, 1999). The biggest potential threat to this community is via frequent and intense fire, which may alter community floristics and structure over time.

Reservation status: Unknown, although examples of this community are found in Badja Swamps NR, Coolumbooka NR, Dangelong NR, Deua NP, Good Good NR, Gourock NP, South East Forest NP, Tallaganda NP, Tallaganda SCA and Wadbilliga NP.

Extent of clearing: Considered minimal.

References: BRS & SFNSW (1999) A report on forest wood resources for Southern NSW CRA Region. Bureau of Rural Sciences and State Forests of NSW New South Wales Government, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Plate e24: Community e24 dominated by *Eucalyptus dalrympleana*, with an open shrub layer of *Bossiaea foliosa* and a patchy understorey of *Poa* spp. and *Microlaena stipoides* var. *stipoides*. Plot UMC219, west of Glenbog SF.

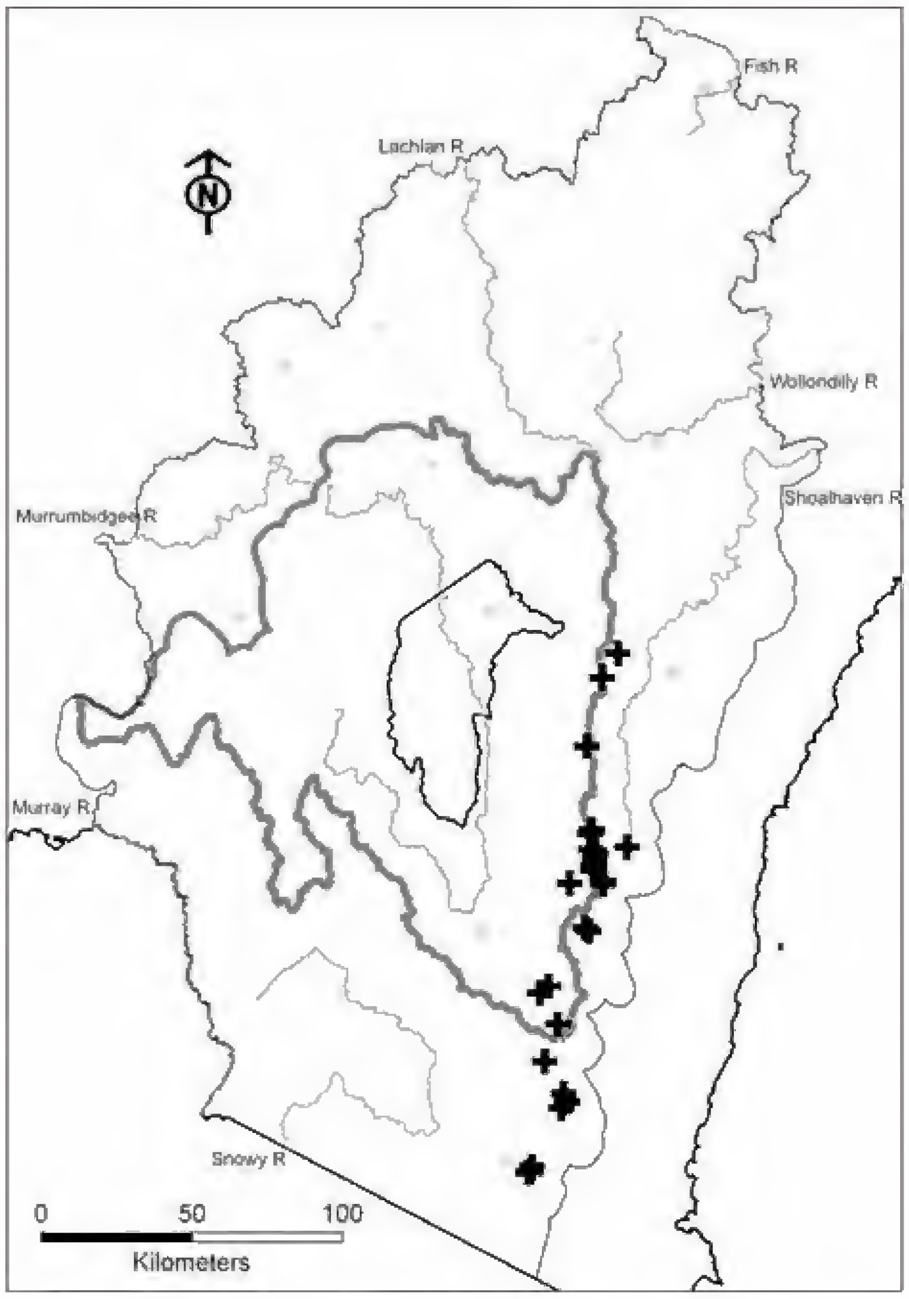

Fig. e24: Distribution of field samples assigned to this community.

m31: Ribbon Gum – Snow Gum – *Cassinia longifolia* tall shrub-grass open forest of gullies in quartz-rich ranges in the Monaro and Kybeyan-Gourock subregions of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus viminalis – Eucalyptus pauciflora* subsp. *pauciflora / Cassinia longifolia – Acacia dealbata / Poa sieberiana – Elymus scaber – Gonocarpus tetragynus – Microlaena stipoides*

Number of samples:	42
Richness [mean (±SD)]:	35 (10)
Slope (degrees):	(4) 7–15 (25)
Altitude (m asl):	(721) 815–947 (1112)
Ave. Annual Rainfall (mm):	(527) 586–694 (846)
Temp. Annual Range (°C):	(23.8) 25.6–26.2 (27.7)

Vegetation Description: Community m31 is a tall open forest to woodland dominated by *Eucalyptus viminalis* and *Eucalyptus pauciflora* subsp. *pauciflora*, frequently with *Eucalyptus rubida* as a co-dominant. A patchy to sparse shrub layer is commonly present, frequently including *Cassinia longifolia* and *Acacia dealbata*, with a groundlayer consisting of a moderately diverse range of grasses, forbs and hard-leaved low shrubs. Commonly occurring species include *Poa sieberiana*, *Elymus scaber*, *Chrysocephalum semipapposum*, *Gonocarpus tetragynus*, *Euchiton japonicus*, *Hypericum gramineum*, *Acaena echinata*, *Microlaena stipoides*, *Hibbertia obtusifolia* and *Scleranthus biflorus*.

Field plots assigned to this community were recorded from gullies and footslopes of minor watercourses on moderately low fertility siliceous substrates along eastern ranges of the tablelands from Tinderry NR south to Cooma and Nimmitabel, with a disjunct occurrence further south in the Merriangaah area. Many records are from the Coornartha-Numeralla-Countegany area. Within this range, this community is found primarily on Adaminaby Group sandstones but also from metamorphics (quartzite and schist) and Glenbog Granodiorite. This community is likely to be restricted to narrow areas of moist deeper soil along drainage lines, grading into Community u21 [*Broad-leaved Peppermint – Candlebark tall dry sclerophyll open forest of quartz-rich ranges of the upper South East Highlands and lower Australian Alps bioregions*] on sheltered footslopes and Community m51 [*Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll open forest on exposed quartz-rich slopes and ridges at primarily in the Monaro and Kybeyan – Gourock subregions of the South Eastern Highlands*] on exposed stony slopes and ridges. As annual rainfall increases to the east and at higher altitudes, this community is replaced in similar moist sandy alluvium habitats by Community p520 [*Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	2	81	2	25	P
Acacia rubida	2	29	1	6	P
Acaena echinata	1	50	1	9	P
Acaena novae-zelandiae	2	52	1	27	P
Ajuga australis	1	29	1	8	P
Bossiaea buxifolia	1	33	1	7	P
Cassinia longifolia	2	88	1	15	P
Chrysocephalum semipapposum	2	55	1	4	P
Daucus glochidiatus	1	24	1	8	P
Desmodium varians	1	36	1	12	P
Dichondra repens	2	45	2	20	P
Echinopogon ovatus	1	43	1	10	P
Elymus scaber	1	69	1	20	P
Epilobium billardierianum subsp. *cinereum*	1	24	1	5	P
Eucalyptus pauciflora subsp. *pauciflora*	3	64	3	20	P
Eucalyptus rubida	3	43	3	8	P
Eucalyptus viminalis	3	71	3	12	P
Euchiton japonicus	1	55	1	15	P
Exocarpos strictus	1	31	1	12	P
Geranium neglectum	1	21	2	2	P
Hypericum gramineum	1	55	1	25	P
Leucopogon fletcheri subsp. *brevisepalus*	1	21	1	3	P
Melichrus urceolatus	1	43	1	13	P
Mirbelia oxylobioides	3	19	1	3	P
Oxalis spp.	1	21	1	3	P
Plantago varia	1	33	1	11	P
Poa sieberiana	2	74	2	48	P
Pultenaea procumbens	1	21	1	4	P
Rumex brownii	1	38	1	9	P
Rytidosperma racemosum	1	40	2	10	P
Scleranthus biflorus	1	40	1	10	P
Veronica perfoliata	1	21	1	4	P
Veronica plebeia	1	19	1	6	P
Viola betonicifolia	1	52	1	27	P
Glycine clandestina	1	45	1	29	C
Gonocarpus tetragynus	2	62	2	48	C
Hibbertia obtusifolia	1	45	1	35	C
Hydrocotyle laxiflora	1	40	2	30	C
Microlaena stipoides	2	55	2	34	C
Themeda australis	1	40	2	21	C

Threatened communities: Components of this community may contain TSC Act 1995– *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions*.

Equivalent vegetation types: This community has no direct equivalent in the Forest Ecosystem classification of Gellie (2005), however it includes many of the plots that were assigned by those studies to Community VG73 [*Eastern Tableland Dry Shrub/Grass Forest*] and Community VG74 [*South Eastern Tablelands Dry Shrub/Grass/Herb Forest*].

Frequently occurring weeds: The greater diversity of weed species found in this community relative to other forested communities in the region might be attributed to the moist, deep soil on which it generally occurs. The most commonly recorded species were *Acetosella vulgaris* (0.21), *Centaurium erythraea* (0.28), *Cirsium vulgare* (0.18), *Hypochaeris radicata* (0.62), and *Trifolium arvense* (0.21), each of which is typical of pastoral environments. This may also indicate some past clearing and/or grazing by domestic stock in this community.

Threats: Although this community occupies relatively moist and productive sites, these generally occupy narrow zones within dry siliceous hills and ranges in dissected terrain. As a result this community is unlikely to have been extensively cleared, although larger examples of the type may have been historically thinned or cleared of trees to encourage pasture growth for grazing stock. Examples of this type on private land are likely to be subject to occasional ongoing light grazing. Its moister landscape position means this type is likely to be prone to ongoing weed invasion, particularly exotic pasture species spread by grazing animals.

Reservation status: Most of the plots assigned to this community were sampled in conservation reserves, including Coornartha NR, Dangelong NR, Macanally SCA, Merriangaah NR, Mount Clifford NR, Numeralla NR, Quidong NR, Strike-a-Light NR, Tinderry NR, Undoo NR and Wadjan NR.

Extent of clearing: Likely to be minor.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate m31: Community m31 beside the Murrumbidgee River near Cooma water filtration plant (plot UMC424), with *Eucalyptus viminalis* above scattered *Acacia dealbata*, *Leptospermum obovatum* and a moist riparian herbaceous groundcover.

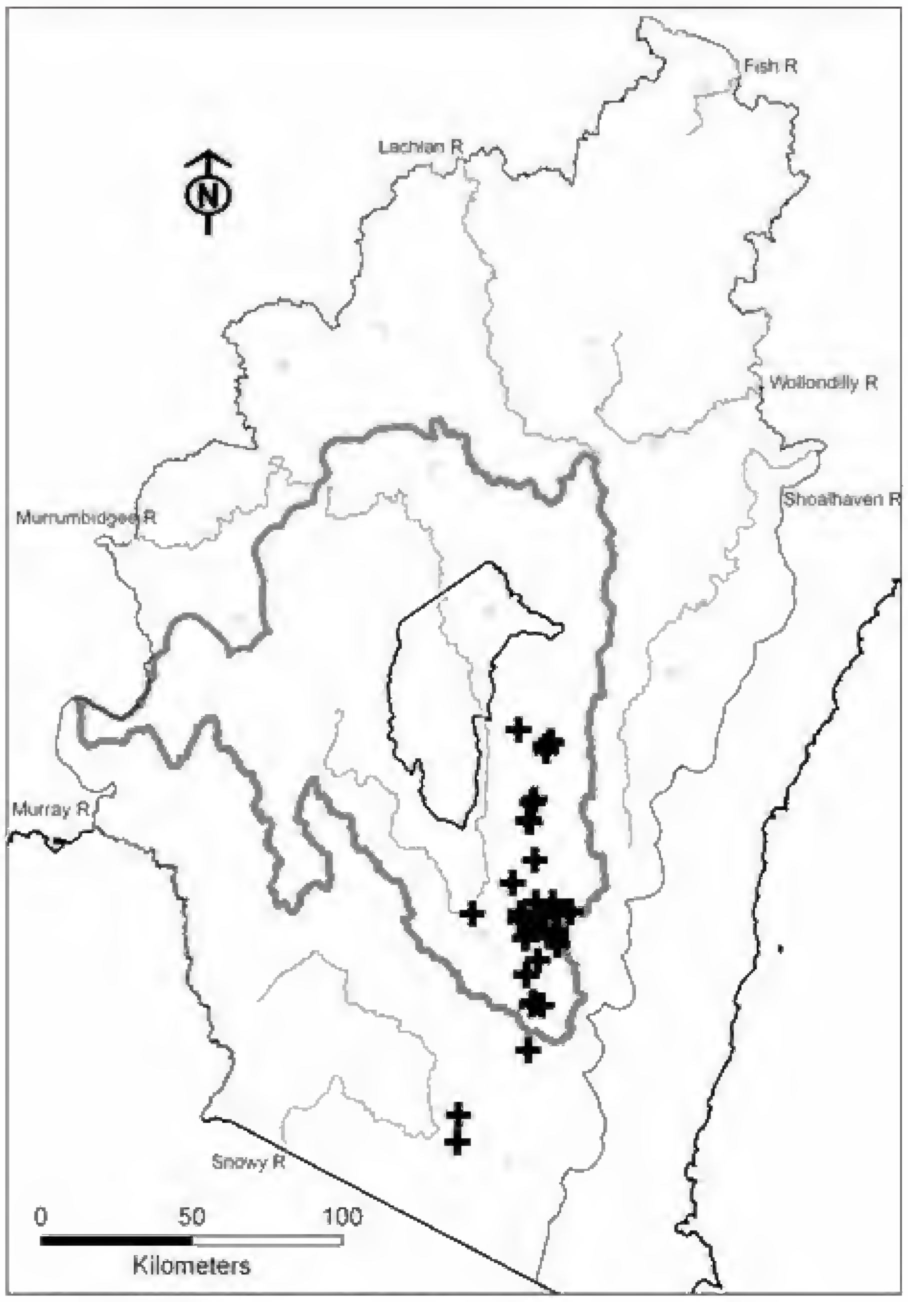

Fig. m31: Distribution of field samples assigned to this community.

m51: Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll open forest on exposed quartz-rich slopes and ridges at primarily in the Monaro and Kybeyan – Gourock subregions of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus mannifera – Eucalyptus rossii – Eucalyptus macrorhyncha – Eucalyptus dives / Hibbertia obtusifolia – Melichrus urceolatus / Rytidosperma pallidum – Pultenaea procumbens – Dianella revoluta*

Number of samples:	50
Richness [mean (±SD)]:	21 (7)
Slope (degrees):	(1) 6–17 (26)
Altitude (m asl):	(771) 851–971 (1196)
Ave. Annual Rainfall (mm):	(539) 591–683 (801)
Temp. Annual Range (°C):	(24.5) 25.6–26.5 (27)

Vegetation Description: Community m51 is a tall eucalypt open forest to woodland with a canopy 10 to 15m tall dominated by *Eucalyptus mannifera* and *Eucalyptus rossii*, commonly with *Eucalyptus dives* and/or *Eucalyptus macrorhyncha*. Shrubs are absent to patchy and a sparse to moderate groundlayer is dominated by a relatively depauperate mix of low shrubs, forbs and grasses, including *Hibbertia obtusifolia*, *Rytidosperma pallidum*, *Dianella revoluta*, *Pultenaea procumbens*, *Melichrus urceolatus* and *Brachyloma daphnoides*.

This community is distributed from the Captains Flat and Burra areas in the north, south along the Tinderry Range and Black Range to Numeralla and Sunny Corner, with disjunct occurrences in the far south from Merriangaah and Quidong on Sherwins Range and Gibraltar Ridge. Within this range, Community m51 occurs on siliceous, moderate to low fertility substrates, occurring primarily on Adaminaby Group sediments (sandstones, siliceous siltstones and mudstones), but also on Jerangle and Cooma Metamorphics and Glenbog Granodiorite.

Community m51 may grade into Community u21 [*Broad-leaved Peppermint – Candlebark tall dry sclerophyll open forest of quartz-rich ranges of the upper South East Highlands and lower Australian Alps bioregions*] on deeper soils on footslopes and flats, and in sheltered gullies may be replaced by Community m31 [*Ribbon Gum – Snow Gum – Cassinia longifolia tall shrub-grass open forest of gullies in quartz-rich ranges in the Monaro and Kybeyan-Gourock subregions of the South Eastern Highlands bioregion*]. On similar exposed landscape positions with siliceous substrates north of Queanbeyan, this community is replaced by the related Community p14 [*Red Stringybark – Scribbly Gum – Rytidosperma pallidum tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia buxifolia	1	14	1	1	P
Acacia falciformis	2	26	2	7	P
Acacia gunnii	1	26	1	6	P
Acacia rubida	1	46	1	5	P
Bossiaea buxifolia	1	32	1	7	P
Brachyloma daphnoides	1	62	1	16	P
Brachyscome rigidula	1	14	1	2	P
Callitris endlicheri	3	16	2	1	P
Cassinia longifolia	1	34	1	16	P
Choretrum pauciflorum	2	14	1	3	P
Daviesia leptophylla	1	22	1	5	P
Daviesia mimosoides subsp. *mimosoides*	1	24	2	9	P
Dianella revoluta	1	66	1	22	P
Dillwynia sericea	1	24	1	4	P

Plate m51: *Eucalyptus mannifera* with hardy shrub taxa typical of plant community m51, adjacent to Dangelong NR, Nimmitabel.

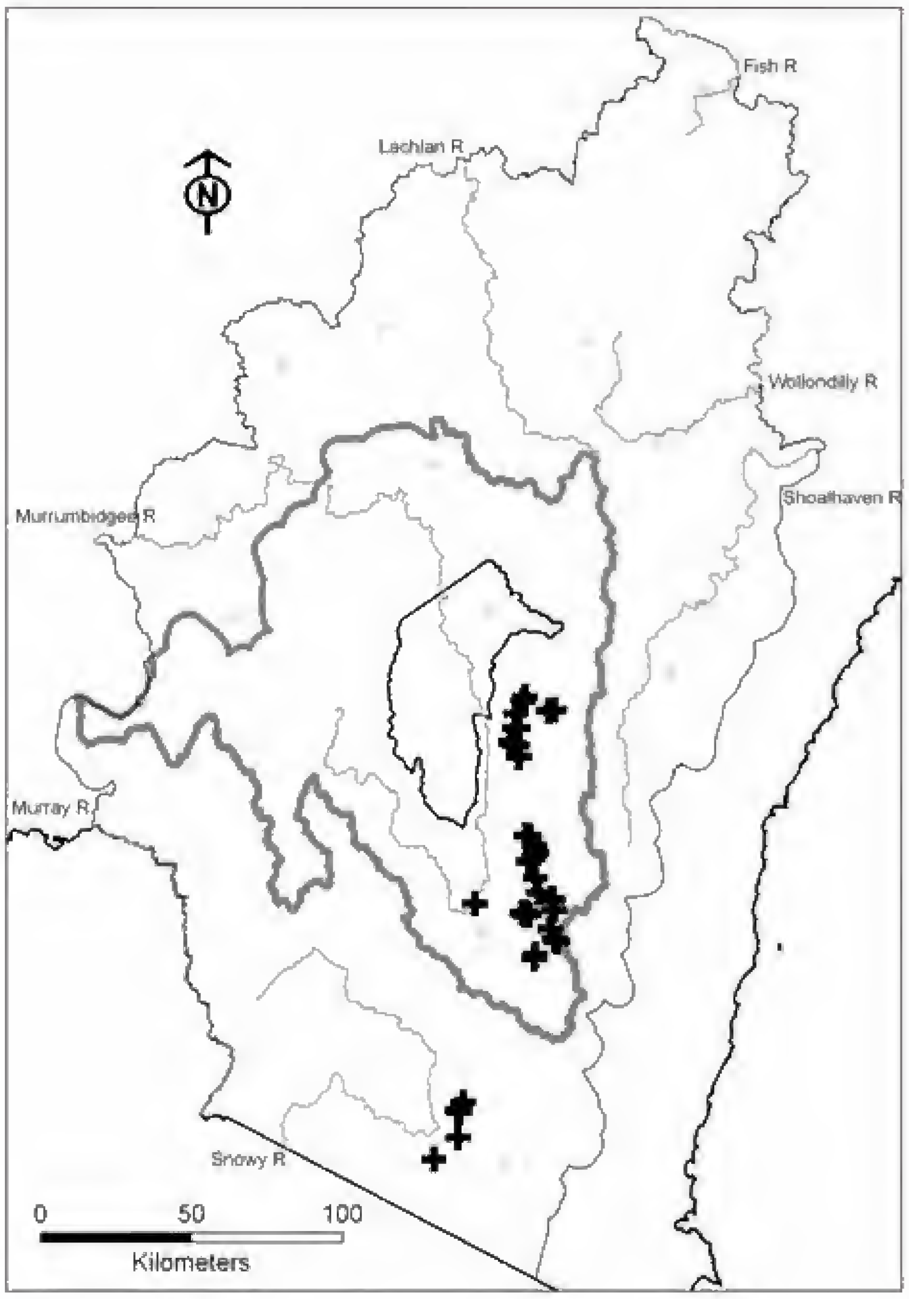

Fig. m51: Distribution of field samples assigned to this community.

Eucalyptus dives	3	50	3	18	P
Eucalyptus macrorhyncha	3	46	3	15	P
Eucalyptus mannifera	3	80	2	10	P
Eucalyptus rossii	3	58	3	7	P
Hibbertia obtusifolia	1	84	1	34	P
Leucopogon ericoides	3	18	1	<1	P
Leucopogon microphyllus	3	22	2	1	P
Melichrus urceolatus	1	62	1	12	P
Persoonia rigida	1	50	1	2	P
Platysace lanceolata	2	18	2	5	P
Pultenaea procumbens	2	66	1	4	P
Rytidosperma pallidum	3	80	2	17	P
Veronica perfoliata	1	22	1	4	P
Gonocarpus tetragynus	1	54	2	48	C
Lomandra longifolia	1	58	2	42	C

Threatened communities: Nil.

Equivalent vegetation types: Community m51 has no direct equivalent in the Forest Ecosystem classification of Gellie (2005), however it includes a number of plots that were assigned to Community VG115 [*South East Tablelands Dry Shrub/Tussock Grass Forest*].

Frequently occurring weeds: Due to the relatively infertile substrate of this community it is generally low in diversity and abundance of weeds, with *Hypochaeris radicata* (0.07) being the most commonly recorded.

Threats: This community occupies relatively infertile and dry rocky slopes and is likely to have suffered only minor clearing across its range. Examples on private land may be subject to stock grazing, but are unlikely to support high stocking rates. Weed invasion is not a significant problem for this community.

Reservation status: Due to the infertile, steep, dry rocky habitat of this community, it is well represented in conservation reserves. This community has been sampled from many conservation reserves across its range, including Burra Creek NR, Yanununbeyan SCA, Tinderry NR, Mount Dowling NR, Macanally NR, Coornatha NR, Kybeyan NR and Merriangaah NR.

Extent of clearing: Only minor clearing likely.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

p8: Silvertop Ash – Narrow-leaved Peppermint shrubby tall dry open forest primarily on sedimentary ridges of the eastern South Eastern Highlands bioregion

Scientific Name: *Eucalyptus sieberi – Eucalyptus radiata* **subsp.** *radiata / Leucopogon lanceolatus – Persoonia linearis – Hibbertia obtusifolia – Pteridium esculentum / Gonocarpus tetragynus – Lomandra longifolia – Poa sieberiana*

Number of samples:	83
Richness [mean (±SD)]:	26 (8)
Slope (degrees):	(1) 6–17 (31)
Altitude (m asl):	(648) 806–994 (1190)
Ave. Annual Rainfall (mm):	(694) 856–956 (1069)
Temp. Annual Range (°C):	(22.6) 24.2–25.2 (26.2)

Vegetation Description: Community p8 is a dry open forest with a tall tree canopy characteristically dominated by *Eucalyptus sieberi*, with or without other eucalypts of dry sites including *Eucalyptus radiata* subsp. *radiata* or *Eucalyptus dives*, and north of the upper Murrumbidee catchment, *Eucalyptus blaxlandii*. This community typically has an open understorey with a sparse complement of hard–leaved tall shrubs, including *Acacia terminalis*, *Persoonia linearis* and *Podolobium ilicifolium* and shorter shrubs such as *Leucopogon lanceolatus, Monotoca scoparia* and the scrambling *Billardiera scandens.* The groundlayer is often dominated by leaf litter and rock, with sparse and scattered plant cover of *Gonocarpus tetragynus*, *Pteridium esculentum*, *Lomandra longifolia*, *Poa sieberiana*, *Dianella revoluta* and *Hibbertia obtusifolia.*

This community occurs primarily on dry exposed ridges and slopes with shallow to skeletal soils of moderately low to low soil fertility derived from a range of quartz-rich sedimentary, acid-volcanic and igneous substrates. It is found extensively on the eastern tablelands, from Jenolan south along the Kanangra Range to Mount Werong, Wiarborough, Wombeyan Caves, the Cookbundoon Range, Currawang, the Gourock, Butmaroo and Bendoura Ranges to the Kybeyan Range (Countegany), and east of Braidwood from Charleys Forest to Northangera and Monga. It extends further to the east beyond the current study area (see Tozer *et al.* 2010).

Community p8 is often associated with Community WSFp73 (described by Tozer *et al*. 2010) north of the study area, and Community p338 [*Brown Barrel wet sclerophyll very tall grass-herb open forest primarily of the Gourock and Tallaganda Ranges in the South Eastern Highlands bioregion*] in the south of its range. Both of these communities occur on deeper, moister soils of lower slopes and more sheltered aspects than Community p8.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia falciformis	1	28	2	7	P
Acacia gunnii	1	18	1	6	P
Acacia obliquinervia	1	12	2	3	P
Acacia obtusifolia	2	10	2	1	P
Acacia terminalis	2	34	1	3	P
Acacia ulicifolia	1	10	1	2	P
Amperea xiphoclada	2	19	1	1	P
Austrostipa rudis	2	12	1	3	P
Banksia spinulosa var. *spinulosa*	2	34	2	1	P
Billardiera scandens	1	49	1	8	P
Bossiaea obcordata	2	7	2	<1	P
Comesperma volubile	1	7	1	1	P
Dampiera purpurea	1	8	2	<1	P
Daviesia ulicifolia	2	22	2	10	P
Dianella caerulea	1	27	1	5	P
Dianella revoluta	2	52	1	22	P
Eucalyptus blaxlandii	2	14	2	<1	P
Eucalyptus radiata subsp. *radiata*	3	58	3	10	P
Eucalyptus sieberi	3	89	3	6	P
Eucalyptus smithii	3	10	1	<1	P
Gonocarpus tetragynus	2	73	2	47	P
Goodenia bellidifolia	1	6	2	1	P
Goodenia hederacea subsp. *hederacea*	2	40	2	16	P
Goodenia spp.	1	6	1	<1	P
Hakea dactyloides	2	17	2	2	P
Hakea eriantha	2	10	1	2	P
Hardenbergia violacea	1	34	1	14	P
Hibbertia diffusa	2	6	2	<1	P
Hibbertia obtusifolia	2	77	1	34	P
Hibbertia serpyllifolia	2	6	2	<1	P
Lepidosperma urophorum	2	19	2	1	P
Leucopogon lanceolatus	2	73	2	11	P
Lomandra filiformis subsp. *coriacea*	2	36	2	18	P
Lomandra glauca	2	23	2	4	P
Lomandra longifolia	2	67	2	42	P
Lomandra multiflora	2	36	1	18	P
Lomandra obliqua	2	24	2	3	P
Lomatia ilicifolia	1	22	1	3	P
Lomatia silaifolia	2	22	2	<1	P
Monotoca scoparia	2	54	1	14	P
Patersonia glabrata	2	18	2	1	P
Patersonia sericea var. *sericea*	1	19	2	3	P
Persoonia laurina	1	8	1	<1	P
Persoonia linearis	1	75	1	9	P
Phyllanthus hirtellus	2	8	1	1	P
Platysace ericoides	2	14	2	<1	P
Podolobium ilicifolium	2	46	2	2	P
Polyscias sambucifolia subsp. *decomposita*	1	12	2	<1	P
Polyscias sambucifolia subsp. *sambucifolia*	2	8	1	1	P
Pomax umbellata	2	28	2	5	P
Pteridium esculentum	2	70	2	26	P
Rhytidosporum procumbens	2	14	1	3	P
Rytidosperma fulvum	3	8	2	1	P
Tetratheca thymifolia	1	11	1	<1	P
Xanthorrhoea concava	2	7	2	1	P
Poa sieberiana	2	53	2	48	C

Threatened communities: Nil.

Equivalent vegetation types: This community is equivalent to Community DSFp8 [*Tableland Ridge Forest*] identified by Tozer *et al.* (2010), with the addition of a small number of new plots from the Monga area and some minor reallocations of plots between this group and the closely related Community DSFp73. It includes a number of plots allocated by Gellie (2005) to Community VG59 [*Eastern Tableland and Escarpment Shrub/Fern Dry Forest*] and Community VG112 [*Eastern Tablelands Dry Shrub Forest*].

Frequently occurring weeds: Weeds are rare probably because the community occurs on soils of low fertility. The most commonly observed species were *Hypochaeris radicata* (0.1), *Oxalis corniculata* (0.03), *Taraxacum officinale* (0.03).

Threats: The steep, dissected, infertile habitat of this type is likely to have largely protected it from broadscale clearing. Parts of its range are within State Forest and private lands subject to logging and grazing. Weed invasion is not a significant threat.

Reservation status: Recorded from within Kanangra–Boyd NP, Blue Mountains NP, Mares Forest NP, Tallaganda NP and SCA, Monga NP and SCA, Budawang NP and Deua NP. Many other reserves have records of p8 immediately adjacent and are likely to contain areas of this type; these reserves include Tarlo River NP, Cookbundoon NR, Gourock NP and Wadbilliga NP.

Extent of clearing: Likely to be minor and scattered, largely restricted to slightly flatter or marginally more fertile examples and edges where this type adjoins habitats more suitable for agricultural development.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Plate p8: Community p8 with *Eucalyptus sieberi* and *Eucalyptus radiata* subsp. *radiata* over a diverse low shrub layer and sparse groundcover, Palerang Fire Trail, Tallaganda SCA.

Plate p9: Community p9 with *Eucalyptus rossii*, *Eucalyptus macrorhyncha* and a sparse understorey dominated by *Rytidosperma pallidum*, on Governor's Hill above Goulburn (plot TOW005HQ).

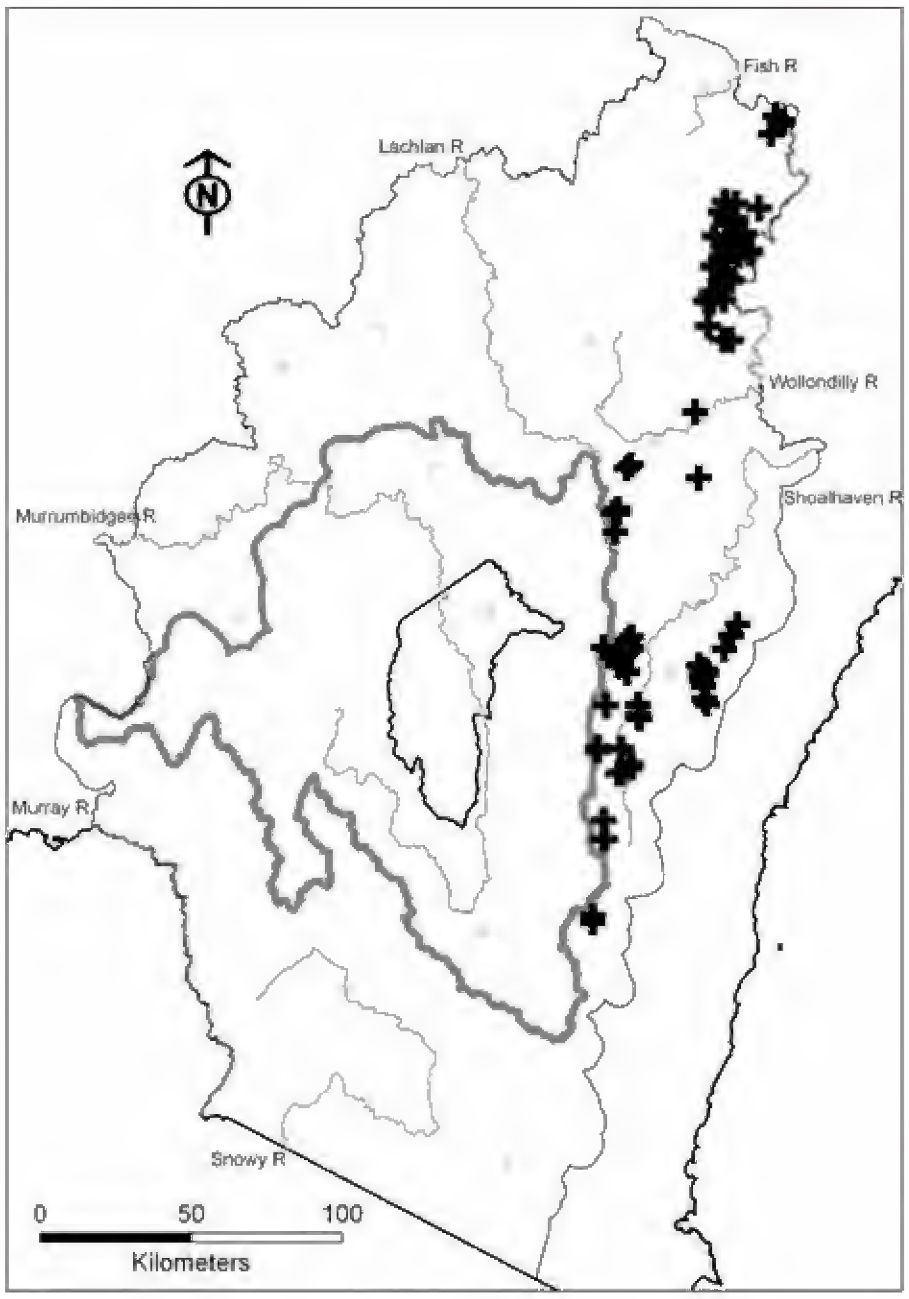

Fig. p8: Distribution of field samples assigned to this community.

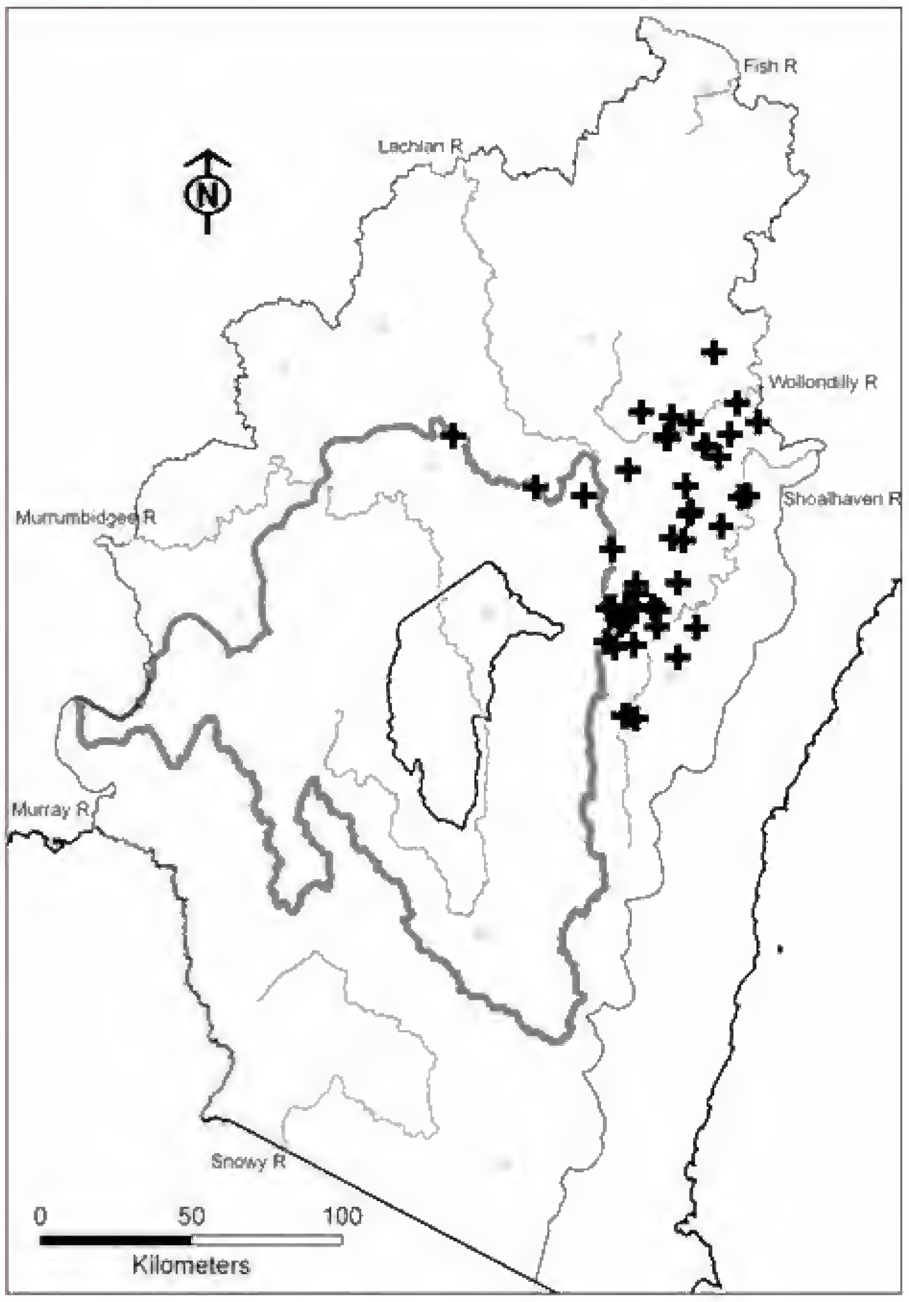

Fig. p9: Distribution of field samples assigned to this community.

p9: Brittle Gum – Scribbly Gum shrubby tall dry open forest on infertile low ridges and hills primarily of the Bungonia subregion of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus mannifera – Eucalyptus rossii / Allocasuarina littoralis / Melichrus urceolatus – Brachyloma daphnoides – Hibbertia obtusifolia / Goodenia hederacea* subsp. *hederacea – Gonocarpus tetragynus – Lomandra filiformis* subsp. *coriacea – Microlaena stipoides – Rytidosperma pallidum*

Number of samples:	51
Richness [mean (±SD)]:	30 (8)
Slope (degrees):	(0) 3–8 (20)
Altitude (m asl):	(560) 649–762 (918)
Ave. Annual Rainfall (mm):	(669) 701–754 (893)
Temp. Annual Range (°C):	(24.7) 25.7–26.2 (26.6)

Vegetation Description: Community p9 is a tall, dry eucalypt woodland to open forest, with a tree canopy commonly dominated by *Eucalyptus mannifera* and/or *Eucalyptus rossii*, often associated with *Eucalyptus dives* and *Eucalyptus macrorhyncha*. A sparse to patchy small tree stratum of *Allocasuarina littoralis* is commonly present, above a sparse understorey of shrubs including *Persoonia linearis*, *Acacia gunnii*, *Daviesia leptophylla* and *Kunzea ericoides*. Groundlayer plants are generally sparse but reasonably diverse, including scattered low shrubs such as *Brachyloma daphnoides*, *Dillwynia sericea*, *Hibbertia obtusifolia*, *Leucopogon virgatus*, *Lissanthe strigosa* and *Melichrus urceolatus*, the grasses *Aristida ramosa*, *Rytidosperma pallidum*, *Microlaena stipoides* and *Poa sieberiana* and the forbs *Dianella revoluta*, *Gonocarpus tetragynus*, *Goodenia hederacea* subsp. *hederacea*, *Lepidosperma gunnii*, *Lomandra filiformis* subsp. *coriacea*, *Lomandra multiflora*, *Opercularia diphylla*, *Hypericum gramineum* and *Lomandra longifolia*.

This community occurs on soils of moderately low to low fertility, derived most commonly from sandstones, quartzites, conglomerates and shales of the Adaminaby, Mount Fairy and Lambie Groups, and, in the Boro, Manar, Bungonia and Marulan areas, on acid volcanic and granitic substrates. This community extends from Big Hill west to Kingsdale, Yarra, Collector and Bellmount, south to Tarago, Butmaroo, Mulloon and Warri and east to Braidwood, Nadgigomar, Windellama, Bungonia, Marulan and Brayton. Within this range, p9 may grade into Community p10 [*Black She-oak – Silvertop Ash tall shrubby dry sclerophyll open forest primarily in the Bungonia subregion of the South Eastern Highlands bioregion*] on sheltered slopes and slightly deeper soils of hills and ridges, while on footslopes it may grade into Community p23 [*Red Stringybark – Broad-leaved Peppermint tall dry sclerophyll grassy open forest on loamy rises primarily in the Bungonia subregion of the South Eastern Highlands bioregion*]. To the west and north of its range it is replaced in similar habitats by the related Community p14 [*Red Stringybark – Scribbly Gum – Rytidosperma pallidum tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia gunnii	1	25	1	6	P
Allocasuarina littoralis	2	52	2	3	P
Aristida ramosa	2	38	2	5	P
Astroloma humifusum	2	25	1	5	P
Austrostipa mollis	2	17	2	<1	P
Brachyloma daphnoides	2	67	1	16	P
Cheilanthes sieberi	1	23	1	9	P
Daviesia leptophylla	2	23	1	5	P
Dianella revoluta	2	69	1	22	P
Dillwynia sericea	1	29	1	4	P
Entolasia stricta	2	27	2	4	P
Eucalyptus dives	3	52	3	18	P
Eucalyptus macrorhyncha	3	38	3	16	P
Eucalyptus mannifera	3	65	3	10	P
Eucalyptus rossii	3	60	3	7	P
Gonocarpus tetragynus	2	85	2	47	P
Goodenia hederacea subsp. *hederacea*	2	94	2	15	P
Hibbertia obtusifolia	2	63	1	34	P
Hovea heterophylla	2	31	1	4	P
Kunzea ericoides	2	25	2	4	P
Laxmannia gracilis	1	21	1	<1	P
Lepidosperma gunnii	2	50	1	4	P
Leucopogon virgatus	2	17	1	3	P
Lissanthe strigosa	2	29	1	7	P
Lomandra filiformis subsp. *coriacea*	2	67	2	18	P
Lomandra multiflora	2	58	1	18	P
Lomandra obliqua	1	21	2	3	P
Melichrus urceolatus	1	71	1	12	P
Microlaena stipoides	2	77	2	34	P
Opercularia diphylla	2	38	2	3	P
Patersonia sericea var. *sericea*	2	25	1	3	P
Persoonia linearis	1	52	1	10	P
Rhytidosporum procumbens	2	23	1	3	P
Rytidosperma pallidum	3	54	2	17	P
Rytidosperma spp.	2	25	1	7	P
Tricoryne elatior	2	21	1	4	P
Hypericum gramineum	1	42	1	25	C
Lomandra longifolia	2	42	2	42	C
Poa sieberiana	2	46	2	48	C

Threatened communities: Nil.

Equivalent vegetation types: This community represents Community DSFp9 [*Tableland Low Woodland*] (Tozer *et al.* 2010) in the context of the upper Murrumbidgee catchment, based on an overlapping but different study area with additional field samples. There is no equivalent community in the classifications of Gellie (2005) as most of the plots in this group are recent samples from private land.

Frequently occurring weeds: Weed species are uncommon and their abundance is low in this community. The ubiquitous *Hypochaeris radicata* (0.29) is the most frequently recorded species.

Threats: Frequent and high-intensity grazing, such as occurs in areas of rural-residential subdivision, threatens remnants of this community. Of particular concern is the disruption this causes to important ecological processes such as seed production and seedling establishment, which may ultimately lead to structural and compositional changes including local extinctions of sensitive plant species. Firewood collection is also likely to represent a threat to components of this community.

Reservation status: Recorded from Tarlo River NP, Belmount SCA, Nadgigomar NR and Scott NR.

Extent of clearing: This type has probably experienced widespread but relatively low clearing levels, with clearing likely to have affected lower hills and the lower edges of patches. Future clearing pressure on remaining examples is most likely in areas of rural-residential subdivision around larger towns.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

p10: Black She-oak – Silvertop Ash tall shrubby dry sclerophyll open forest primarily in the Bungonia subregion of the South Eastern Highlands bioregion

Scientific Name: *Allocasuarina littoralis – Eucalyptus sieberi – Eucalyptus agglomerata / Persoonia linearis – Hibbertia obtusifolia / Goodenia hederacea* subsp. *hederacea – Lomandra obliqua – Microlaena stipoides – Pomax umbellata*

Number of samples:	53
Richness [mean (±SD)]:	30 (9)
Slope (degrees):	(0) 3–10 (27)
Altitude (m asl):	(589) 663–789 (919)
Ave. Annual Rainfall (mm):	(695) 730–769 (866)
Temp. Annual Range (°C):	(23.5) 25.3–25.7 (26.3)

Vegetation Description: Community p10 is a dry tall open eucalypt forest with a canopy dominated by *Eucalyptus sieberi* and *Eucalyptus agglomerata*, usually with a sparse to dense small tree layer of *Allocasuarina littoralis* and scattered shrubs, including *Acacia terminalis* and *Persoonia linearis.* The groundlayer tends to be dominated by leaf litter, with a sparse scatter of grasses, sedges, forbs and low shrubs including *Billardiera scandens*, *Entolasia stricta*, *Goodenia hederacea* subsp. *hederacea*, *Hibbertia obtusifolia*, *Lepidosperma gunnii*, *Lomandra multiflora*, *Lomandra obliqua*, *Microlaena stipoides* and *Pomax umbellata*.

This community occurs on dry ridges and slopes, on soils of moderately low fertility derived predominantly from sedimentary and metasedimentary rocks of the Adaminaby, Lambie and Shoalhaven Groups and the Towrang and Gundary Beds, which are predominantly shales, sandstones, quartzites and conglomerates. It occurs from Greenwich Park and Chatsbury in the north, south to Larbert and Durran Durra, west to Collector and east beyond the study area boundary. While not sampled in the ACT, similar vegetation observed around Gibraltar Hill may be a western outlier or represent a variant of this community.

This community is often associated with other dry ridge forests across its range. It commonly occupies lower ridges and slopes of tableland hills, and may grade into Community p8 [*Silvertop Ash – Narrow-leaved Peppermint shrubby tall dry open forest*] on high stony tableland ridges, while on lower slopes it is often replaced by Community p9 [*Brittle Gum – Scribbly Gum shrubby tall dry open forest*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia obtusifolia	2	15	2	1	P
Acacia terminalis	1	53	2	3	P
Allocasuarina littoralis	3	83	2	3	P
Banksia spinulosa var. *spinulosa*	2	17	2	2	P
Billardiera scandens	1	53	1	9	P
Brachyloma daphnoides	1	34	1	16	P
Caustis flexuosa	1	13	2	<1	P
Daviesia leptophylla	2	26	1	5	P
Dianella revoluta	1	43	1	22	P
Entolasia stricta	2	53	1	3	P
Eucalyptus agglomerata	3	64	3	2	P
Eucalyptus globoidea	3	25	3	2	P
Eucalyptus rossii	3	21	3	7	P
Eucalyptus sieberi	3	83	3	7	P
Goodenia hederacea subsp. *hederacea*	2	98	2	16	P
Hakea dactyloides	2	23	2	3	P
Helichrysum leucopsideum	2	19	1	<1	P
Hibbertia empetrifolia	2	17	2	<1	P
Hibbertia obtusifolia	1	77	1	34	P

Plate p10: An example of Community p10 near Tiyces Lane, Towrang, with a canopy dominated by *Eucalyptus sieberi*, a very sparse understorey and groundcover dominated by leaf litter.

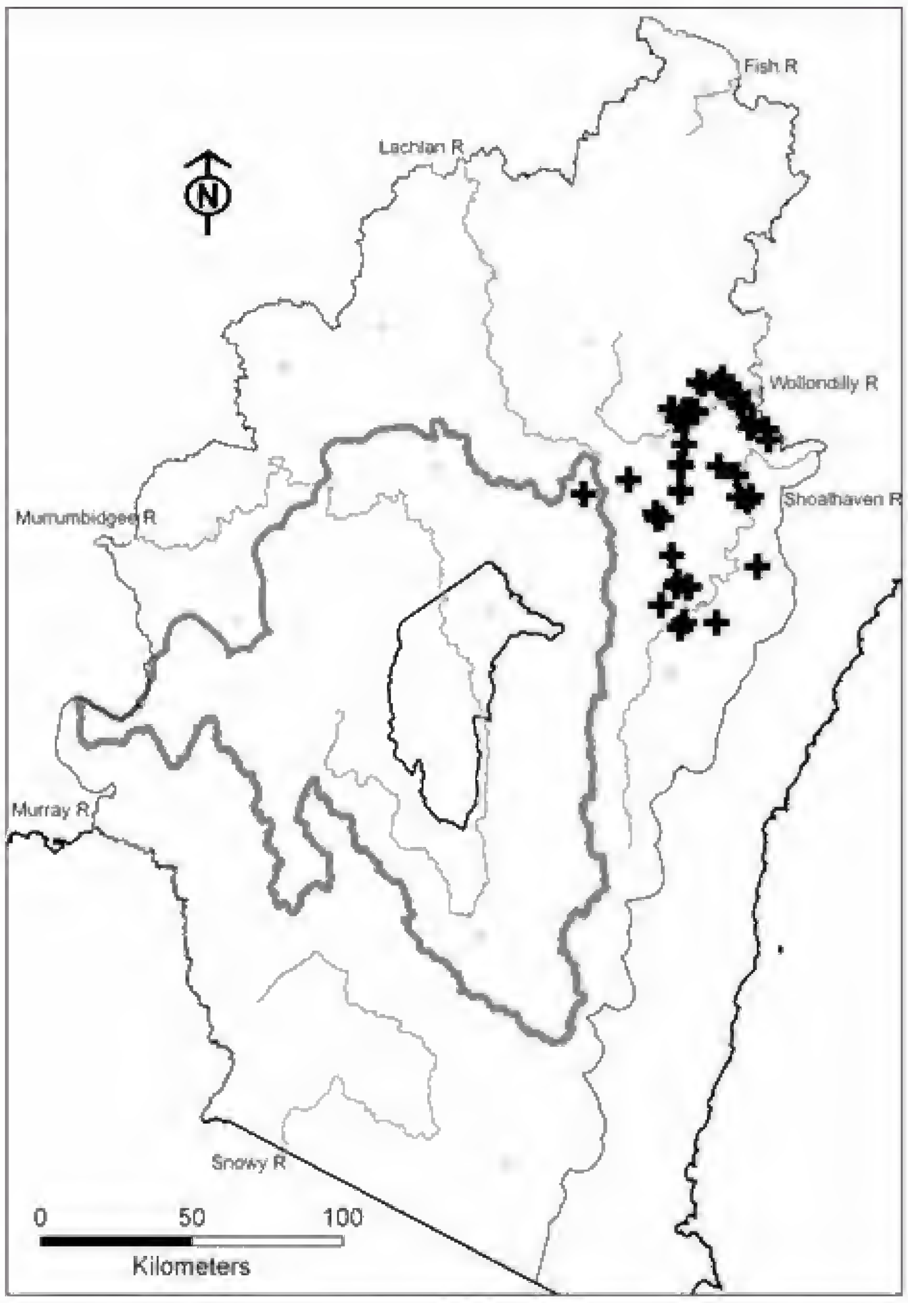

Fig. p10: Distribution of field samples assigned to this community.

Lepidosperma gunnii	1	55	1	4	P
Lepidosperma urophorum	2	15	2	1	P
Lomandra glauca	1	23	2	4	P
Lomandra multiflora	1	51	1	18	P
Lomandra obliqua	2	70	2	2	P
Lomatia ilicifolia	2	30	1	3	P
Melichrus urceolatus	1	43	1	13	P
Microlaena stipoides	2	57	2	34	P
Monotoca scoparia	1	32	1	15	P
Opercularia aspera	1	19	1	3	P
Opercularia diphylla	2	21	2	3	P
Patersonia glabrata	2	28	2	1	P
Patersonia sericea var. *longifolia*	2	23	2	<1	P
Patersonia sericea var. *sericea*	1	38	2	3	P
Persoonia linearis	1	92	1	9	P
Persoonia mollis subsp. *livens*	1	13	1	1	P
Platysace ericoides	2	30	2	<1	P
Platysace lanceolata	2	25	2	5	P
Podolobium ilicifolium	1	26	2	3	P
Pomax umbellata	1	66	2	4	P
Rhytidosporum procumbens	1	49	1	2	P
Rytidosperma pallidum	2	40	2	17	P
Stypandra glauca	2	49	2	5	P
Xanthorrhoea concava	2	30	2	<1	P
Gonocarpus tetragynus	2	45	2	48	C

Threatened communities: Nil.

Equivalent vegetation types: Community p10 represents a slight westward extension of Community DSFp10 [*Eastern Tablelands Dry Forest*] identified by Tozer *et al.* (2010), with the addition of new plots from Collector and recently acquired reserves around Goulburn. This community extends beyond the current study area's eastern boundary. It has floristic affinities with VG15 [*North East Tableland Dry Shrub Forest*] of Gellie (2005).

Frequently occurring weeds: Because this community occurs on poor soils, weeds are infrequent. The ubiquitous *Hypochaeris glabra* (0.09) is the most frequently recorded weed species in this community.

Threats: This community is commonly found as remnant patches of woody vegetation on poor soils on hills and ridges in rural landscapes where communities of better soils have been cleared. Some of its original extent is likely to have been cleared, and most remnants on private land are likely to be subject to ongoing light grazing. Where this community occurs on public land, frequent hazard reduction burning has the potential to eliminate important structural elements, such as the *Allocasuarina littoralis* dominated midstorey.

Reservation status: This community is known to occur in Tarlo River NP, Cookbundoon NR, Pomaderris NR, Bungonia SCA, Morton NP (western edge) and Nadgigomar NR.

Extent of clearing: This community is only likely to have undergone minor clearing across its range, predominantly at the edges of patches where it adjoins areas of slightly deeper and/or more fertile soils.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

p14: Red Stringybark – Scribbly Gum – *Rytidosperma pallidum* tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion

Scientific Name: *Eucalyptus macrorhyncha – Eucalyptus rossii ± Eucalyptus mannifera / Hibbertia obtusifolia – Brachyloma daphnoides – Daviesia leptophylla / Rytidosperma pallidum – Gonocarpus tetragynus – Poa sieberiana*

Number of samples:	165
Richness [mean (±SD)]:	27 (8)
Slope (degrees):	(0) 5–16 (51)
Altitude (m asl):	(504) 703–856 (1157)
Ave. Annual Rainfall (mm):	(603) 712–790 (918)
Temp. Annual Range (°C):	(24.1) 25.8–26.6 (28.1)

Vegetation Description: Community p14 is a tall open eucalypt forest dominated by *Eucalyptus macrorhyncha* and *Eucalyptus rossii*, often with *Eucalyptus mannifera*, *Eucalyptus goniocalyx*, *Eucalyptus dives* or *Eucalyptus polyanthemos*. The shrub layer is patchy and generally includes *Hibbertia obtusifolia*, *Brachyloma daphnoides*, *Daviesia leptophylla*, *Acacia gunnii* and *Hovea linearis* and occasionally *Melichrus urceolatus*, *Monotoca scoparia*, *Persoonia rigida* and *Gompholobium huegellii*. The climbing or prostrate sub-shrub *Hardenbergia violacea* is often present. The groundlayer is also generally patchy and dominated by grasses such as *Rytidosperma pallidum* and *Poa sieberiana* and a variety of forbs including *Lomandra filiformis* subsp. *coriacea*, *Dianella revoluta*, *Lomandra multiflora*, *Gonocarpus tetragynus* and *Goodenia hederacea* subsp. *hederacea*.

This community is widely distributed, occurring within the Murrumbidgee catchment mostly in areas north of the Wee Jasper and Captains Flat areas to Oberon in the Central West catchment. It grades into communities such as Community m51 [*Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll open forest on exposed quartz-rich slopes and ridges at primarily in the Monaro and Kybeyan – Gourock subregions of the South Eastern Highlands*] south of Queanbeyan, as well as Community p23 [*Red Stringybark – Broad-leaved Peppermint tall dry sclerophyll grassy open forest on loamy rises primarily in the Bungonia subregion of the South Eastern Highlands bioregion*] and Community p24 [*Yellow Box – Blakely's Red Gum tall grassy woodland on undulating sedimentary and acid-volcanic substrates in the Goulburn area of the South Eastern Highlands bioregion*] on more gently undulating sites with loamy soils.

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia buxifolia	1	8	1	1	P
Acacia decurrens	1	6	2	1	P
Acacia falciformis	1	15	2	7	P
Acacia genistifolia	2	11	1	1	P
Acacia gunnii	1	44	1	4	P
Acacia lanigera	1	4	0	0	P
Astrotricha ledifolia	1	4	1	<1	P
Brachyloma daphnoides	2	62	1	14	P
Caladenia carnea	1	4	1	1	P
Cassinia arcuata	1	8	2	1	P
Cheiranthera linearis	1	13	1	<1	P
Comesperma ericinum	2	3	1	<1	P
Daviesia leptophylla	2	51	1	3	P
Dianella revoluta	1	63	1	20	P
Dillwynia phylicoides	2	16	2	1	P
Dillwynia sericea	1	26	1	3	P
Dillwynia sieberi	1	4	1	<1	P

Dillwynia spp.	2	4	1	<1	P
Diuris sulphurea	1	5	1	1	P
Drosera auriculata	1	8	1	2	P
Eucalyptus dives	3	30	3	18	P
Eucalyptus goniocalyx	2	34	3	2	P
Eucalyptus macrorhyncha	3	86	3	12	P
Eucalyptus mannifera	3	51	2	9	P
Eucalyptus polyanthemos	3	22	3	2	P
Eucalyptus praecox	3	2	0	0	P
Eucalyptus rossii	3	66	3	4	P
Genoplesium spp.	1	4	1	<1	P
Glossodia major	1	3	1	<1	P
Gompholobium huegelii	1	20	1	4	P
Gompholobium minus	1	5	1	1	P
Gonocarpus tetragynus	2	84	2	46	P
Goodenia bellidifolia	2	8	2	1	P
Goodenia hederacea subsp. *hederacea*	2	67	2	15	P
Hakea decurrens subsp. *decurrens*	2	2	1	<1	P
Hardenbergia violacea	1	34	1	13	P
Hibbertia calycina	1	6	2	<1	P
Hibbertia obtusifolia	1	89	1	32	P
Hibbertia riparia	1	11	1	<1	P
Hibbertia spp.	1	4	1	<1	P
Hovea heterophylla	2	13	1	4	P
Hovea linearis	1	40	1	12	P
Leptospermum multicaule	2	5	2	<1	P
Leucopogon virgatus	1	15	1	3	P
Lomandra filiformis subsp. *coriacea*	2	61	2	17	P
Lomandra multiflora	1	45	1	17	P
Melichrus urceolatus	1	37	1	12	P
Monotoca scoparia	1	31	1	14	P
Olearia microphylla	1	4	2	<1	P
Patersonia sericea var. *sericea*	1	9	2	3	P
Persoonia rigida	1	21	1	2	P
Phyllanthus hirtellus	1	8	1	1	P
Poa sieberiana	2	73	2	47	P
Pomax umbellata	1	12	2	5	P
Pterostylis spp.	1	19	1	5	P
Pultenaea microphylla	2	11	1	<1	P
Pultenaea procumbens	1	11	1	4	P
Pultenaea subspicata	1	7	2	2	P
Rhytidosporum procumbens	1	14	1	3	P
Rytidosperma fulvum	3	8	2	1	P
Rytidosperma pallidum	3	74	2	15	P
Senecio tenuiflorus	2	7	1	2	P
Stypandra glauca	1	17	2	5	P
Styphelia triflora	1	8	1	<1	P
Tetratheca spp.	1	2	1	<1	P
Thelymitra spp.	1	11	1	2	P
Thysanotus patersonii	1	5	1	<1	P
Wahlenbergia gracilis	2	12	1	6	P

Threatened communities: Nil.

Equivalent vegetation types: This community represents Community DSF p14 [*Western Tablelands Dry Forest*] as described by Tozer *et al.* (2010), with a western range extension into the upper Murrumbidgee catchment. The relationship between Community p14 and communities identified by Benson *et al.* (2010) with similar structural dominants outside the upper Murrumbidgee catchment (such as VCA 290, VCA 349 and VCA 351) requires resolution through further sampling and analysis.

Frequently occurring weeds: As with other communities occurring on soils of low fertility, weeds are an uncommon component of this community. *Hypochaeris glabra* (0.14), *Hypochaeris radicata* (0.29) are the most frequently recorded weeds, which is not surprising given the dispersive nature and colonising potential of these species.

Threats: This community is generally found on undulating terrain, and in close proximity to intensively managed farmland. As a consequence, moderate areas have been cleared and used for grazing. Where intensive

Plate p14: Community p14 with *Eucalyptus macrorhyncha*, *Eucalyptus mannifera*, *Eucalyptus rossii* and groundcover dominated by *Rhytidosperma pallidum*, above Soldiers Gully near Burra Burra Creek (plot RIC002LQ).

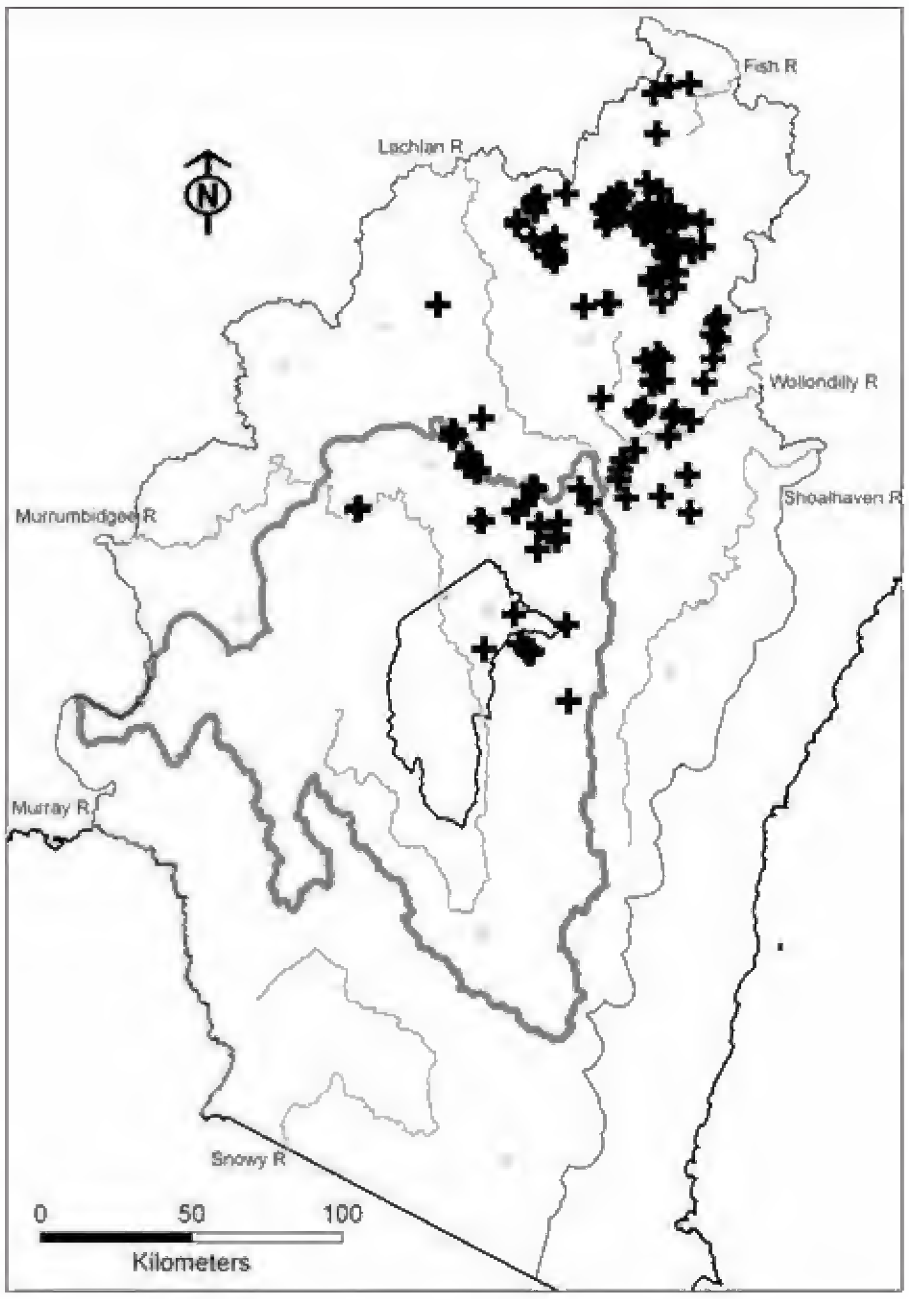

Fig. p14: Distribution of field samples assigned to this community.

grazing occurs, this has the potential to compromise community structure and species richness. On private property the collection of fallen timber for firewood is likely to be a threat to populations of ground-dwelling fauna.

Reservation status: Considered to be moderately well reserved. Examples of this community are found in Abercrombie River NP, Back Arm NR, Bango NR, Belmount SCA, Gillindich NR, Keverstone NP, McLeods Creek NR, Morton NP, Mundoonen NR, Razorback NR, Tarlo River NP, Wee Jasper NR and Yanununbeyan NP.

Extent of clearing: Although this community generally occurs on nutrient deficient lithosols on low undulating hills, it is moderately cleared due to its broad extent and occurrence on gentle slopes.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

p23: Red Stringybark – Broad-leaved Peppermint tall dry sclerophyll grassy open forest on loamy rises primarily in the Bungonia subregion of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus macrorhyncha – Eucalyptus dives / Melichrus urceolatus – Hibbertia obtusifolia – Hardenbergia violacea / Microlaena stipoides – Lomandra filiformis* subsp. *coriacea – Hydrocotyle laxiflora – Gonocarpus tetragynus – Themeda australis – Poa sieberiana*

Number of samples:	86
Richness [mean (±SD)]:	36 (9)
Slope (degrees):	(0) 3–11 (37)
Altitude (m asl):	(531) 661–856 (1118)
Ave. Annual Rainfall (mm):	(664) 700–790 (940)
Temp. Annual Range (°C):	(24) 25.5–26.3 (28.3)

Vegetation Description: Community p23 is a tall open forest or woodland most commonly dominated by *Eucalyptus macrorhyncha* and *Eucalyptus dives*, often with a mix of other eucalypts including *Eucalyptus bridgesiana*, *Eucalyptus mannifera* and *Eucalyptus melliodora*. Taller shrubs are frequently absent, but some plots have a sparse small tree layer of acacias and a sparse to patchy shrub stratum. The groundlayer is commonly moderate to dense, with the most frequent taxa being *Lomandra filiformis* subsp. *coriacea* and a mix of grasses (e.g. *Microlaena stipoides*, *Themeda australis*, *Poa sieberiana*), low shrubs (*Hibbertia obtusifolia*, *Melichrus urceolatus*), and forbs (*Gonocarpus tetragynus*, *Goodenia hederacea* subsp. *hederacea*, *Hydrocotyle laxiflora*, *Hypericum gramineum* and *Oxalis perennans*).

This community occupies gently undulating to hilly country in the north-eastern Southern Tablelands, and is recorded from an area bounded by Tuena, Arkstone and Paling Yards in the north; Crooked Corner, Lost River, Bannister, Parkesbourne, Collector and Tarago in the southwest; and Larbert, Braidwood and Tomboye in the southeast. It extends to the east beyond the current study area boundary on similar undulating tableland country. Plots assigned to this type are commonly on sandy soils of intermediate depth and moderately low to low fertility derived from substrates including Adaminaby and Lambie Group sedimentary rocks and various granitic and acid volcanic rocks.

The floristic composition of Community p23 is intermediate between vegetation of drier hills with shallow soil, and vegetation of gentle slopes and flats with deeper soils and better groundwater availability. On gentler slopes and flats this type may grade into p24 [*Yellow Box – Blakely's Red Gum tall grassy woodland on undulating sedimentary and acid-volcanic substrates in the Goulburn area of the South Eastern Highlands bioregion*], while on steeper slopes with shallower soils it is generally replaced by dry sclerophyll forest types such as p9 [*Brittle Gum – Scribbly Gum shrubby tall dry open forest on infertile low ridges and hills primarily of the Bungonia subregion of the South Eastern Highlands bioregion*] or p14 [*Red Stringybark – Scribbly Gum – Rytidosperma pallidum tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion*]. The majority of plots allocated to this community are from private land subject to regular stock grazing, fencepost cutting and other disturbances, which may help to explain the highly variable shrub and canopy composition of this type.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia decurrens	2	14	1	1	P
Acacia genistifolia	1	12	1	1	P
Acaena echinata	2	22	1	9	P
Aristida jerichoensis var. *jerichoensis*	2	13	2	<1	P
Aristida ramosa	2	29	2	5	P
Astroloma humifusum	1	22	1	5	P
Austrostipa densiflora	2	8	1	<1	P
Austrostipa mollis	3	7	2	<1	P
Austrostipa rudis	2	8	2	1	P
Austrostipa scabra	2	12	1	4	P
Bossiaea buxifolia	2	31	1	6	P
Bossiaea prostrata	2	20	1	2	P
Cassinia arcuata	1	8	1	1	P
Cassinia laevis	1	7	2	1	P
Cheilanthes sieberi	2	37	1	8	P
Chrysocephalum apiculatum	2	19	1	6	P
Cymbonotus lawsonianus	1	30	1	4	P
Daviesia latifolia	2	21	2	7	P
Dianella longifolia	1	9	1	3	P
Dichelachne micrantha	2	33	1	9	P
Dillwynia sericea	1	13	1	4	P
Echinopogon caespitosus	1	10	1	<1	P
Einadia nutans	1	17	1	4	P
Elymus scaber	2	35	1	21	P
Eucalyptus blakelyi	3	14	3	2	P
Eucalyptus bridgesiana	2	29	3	7	P
Eucalyptus cinerea	3	13	2	<1	P
Eucalyptus dives	3	56	3	17	P
Eucalyptus macrorhyncha	3	56	3	15	P
Eucalyptus mannifera	2	29	3	11	P
Eucalyptus melliodora	3	21	3	5	P
Galium gaudichaudii	2	22	1	9	P
Geranium solanderi	2	35	1	19	P
Glycine microphylla	2	7	2	1	P
Gonocarpus tetragynus	2	90	2	47	P
Goodenia hederacea subsp. *hederacea*	2	69	2	15	P
Hardenbergia violacea	2	42	1	14	P
Hibbertia obtusifolia	2	64	1	34	P
Hovea heterophylla	2	24	1	4	P
Hydrocotyle laxiflora	2	84	2	28	P
Hypericum gramineum	2	76	1	24	P
Indigofera australis	1	16	1	7	P
Juncus filicaulis	1	10	1	2	P
Juncus subsecundus	1	8	1	2	P
Lagenophora gracilis	2	9	1	1	P
Laxmannia gracilis	2	6	1	1	P
Lissanthe strigosa	2	38	1	6	P
Lomandra filiformis subsp. *coriacea*	2	90	2	17	P
Lomandra multiflora	2	37	1	18	P

Luzula densiflora	1	22	1	5	P
Melichrus urceolatus	2	60	1	12	P
Microlaena stipoides	2	93	2	33	P
Opercularia aspera	2	16	1	3	P
Opercularia diphylla	2	23	2	3	P
Opercularia hispida	2	12	1	2	P
Oxalis perennans	2	70	1	12	P
Ozothamnus diosmifolius	1	7	1	<1	P
Panicum effusum	1	10	1	3	P
Pimelea curviflora	2	29	1	6	P
Plantago gaudichaudii	2	12	1	1	P
Pterostylis spp.	1	19	1	6	P
Pultenaea microphylla	2	9	1	1	P
Rytidosperma laeve	2	23	2	3	P
Rytidosperma monticola	2	6	2	1	P
Rytidosperma racemosum	2	44	2	10	P
Rytidosperma tenuius	2	10	2	<1	P
Solenogyne dominii	1	13	1	3	P
Solenogyne gunnii	2	13	1	5	P
Thelymitra spp.	1	10	1	2	P
Themeda australis	2	62	2	20	P
Thysanotus patersonii	2	10	1	<1	P
Tricoryne elatior	2	29	1	3	P
Veronica plebeia	2	34	1	5	P
Wahlenbergia gracilis	1	19	1	6	P
Poa sieberiana	2	57	2	48	C

Threatened communities: Components of this community may be considered part of TSC Act 1995 – *White Box Yellow Box Blakely's Red Gum Woodland* and EPBC Act 1999 – *White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derived Native Grassland.*

Equivalent vegetation types: This community represents Community GWp23 [*Tableland Hills Grassy Woodland*] (Tozer *et al.* 2010) in the context of this study, based on an overlapping but different study area with additional field samples from the tablelands and slopes.

Frequently occurring weeds: The weeds *Acetosella vulgaris* (0.35) and *Hypochaeris radicata* (0.61) are relatively common in this community, reflecting its proximity to land managed for grazing.

Threats: Frequent and high-intensity grazing, such as occurs in areas of rural-residential subdivision, threatens remnants of this community. Of particular concern is the disruption this causes to important ecological processes such as seed production and seedling establishment, which may ultimately lead to structural and compositional changes including local extinctions of sensitive plant species. Firewood collection is also likely to represent a threat to components of this community.

Reservation status: The distribution of this community generally corresponds with freehold land and this community is not well represented in the conservation reserve system. Small areas are present in the newer reserves of Gillindich NR, Mares Forest NP and Oakdale NR and immediately adjacent to Abercrombie River NP and Bungonia NP, none of which occur within the upper Murrumbidgee catchment.

Extent of clearing: This community has probably experienced widespread though only moderate levels of clearing, because it tends to occupy habitats of intermediate utility for agricultural development. Clearing is likely to have disproportionately affected examples on better soils, but also along the edges of patches on poorer soils. Future clearing pressure on remaining examples is most likely in areas of rural-residential subdivision around larger towns.

Reference: Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Plate p23: Community p23 on "Arthursleigh", west of Canyonleigh, with *Eucalyptus dives*, *Eucalyptus macrorhyncha* and a grazed grassy groundcover (plot CAN039LQ).

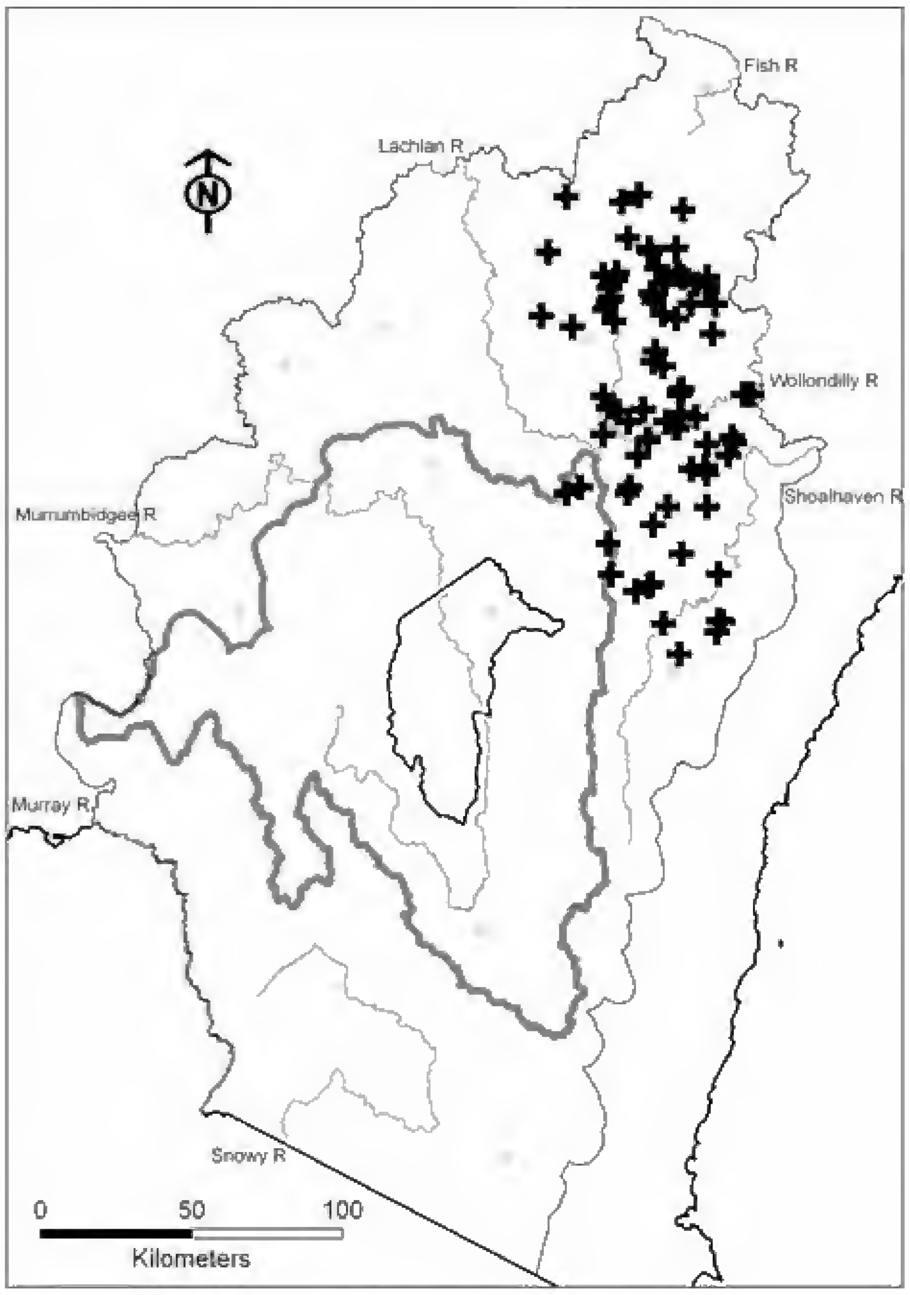

Fig. p23: Distribution of field samples assigned to this community.

u18: Mealy Bundy – Broad-leaved Peppermint shrubby mid-high open forest on granite substrates primarily in the Namadgi region

Scientific Name: *Eucalyptus nortonii – Eucalyptus dives / Cassinia longifolia – Hibbertia obtusifolia – Olearia tenuifolia / Gonocarpus tetragynus – Dichelachne micrantha – Wahlenbergia stricta – Hydrocotyle laxiflora*

Number of samples:	17
Richness [mean (±SD)]:	26 (7)
Slope (degrees):	(8) 15–23 (35)
Altitude (m asl):	(730) 818–978 (1318)
Ave. Annual Rainfall (mm):	(735) 789–958 (1072)
Temp. Annual Range (°C):	(24.1) 25.5–26 (26.3)

Vegetation Description: Community u18 is a mid-high open forest dominated by *Eucalyptus nortonii* and *Eucalyptus dives*, with occasional occurrences of dense stands of *Callitris endlicheri* occurring in either the canopy or midstorey. The shrub layer is generally dense and may be dominated by taxa including *Cassinia longifolia*, *Olearia tenuifolia*, *Brachyloma daphnoides*, *Kunzea ericoides*, *Calytrix tetragona* and/or *Acacia falciformis*. The groundlayer is usually sparse and frequently includes the forbs *Gonocarpus tetragynus*, *Wahlenbergia stricta* and *Hydrocotyle laxiflora* and the low shrub *Hibbertia obtusifolia*. *Dichelachne micrantha* is the most common grass, with occasional occurrences of *Rytidosperma pallidum* and *Rytidosperma pilosum*.

This community was sampled in the ACT, primarily in Namadgi NP in the Mount Tennant area and slopes around Blue Gum Creek, however it may potentially occur in other parts of the Brindabella Ranges including in NSW on earthy sands derived from granite substrates. In Namadgi NP it grades into communities such as Community u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*], Community u29 [*Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of the South Eastern Highlands bioregion*], Community u66 [*Mealy Bundy – Red Stringybark grass-herb mid-high open forest of the South Eastern Highlands and Upper Slopes subregion of the South Western Slopes bioregion*] and Community u27 [*Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia falciformis	3	41	2	7	P
Brachyloma daphnoides	1	59	1	16	P
Bursaria spinosa	2	35	1	10	P
Callitris endlicheri	4	35	2	1	P
Calytrix tetragona	3	47	2	<1	P
Cassinia longifolia	3	100	1	16	P
Cheilanthes austrotenuifolia	3	24	1	3	P
Dichelachne micrantha	3	53	1	10	P
Dillwynia sericea	2	24	1	4	P
Dodonaea viscosa	3	24	1	2	P
Eucalyptus dives	3	65	3	18	P
Eucalyptus nortonii	3	100	3	3	P
Hibbertia obtusifolia	2	76	1	34	P
Kunzea ericoides	2	53	2	4	P
Leucopogon attenuatus	2	29	1	1	P
Olearia tenuifolia	2	65	1	<1	P
Oxalis exilis	2	35	1	5	P
Pomax umbellata	3	35	2	5	P
Pultenaea procumbens	1	35	1	4	P
Senecio quadridentatus	1	29	1	6	P
Stypandra glauca	2	29	2	5	P
Thysanotus tuberosus	1	41	1	3	P

Plate u18: Community u18 showing *Eucalyptus nortonii* and shrubs including *Cassinia longifolia* and *Acacia dealbata*, with the ground layer covered with leaf litter. Bluegum Ck., Namadgi NP.

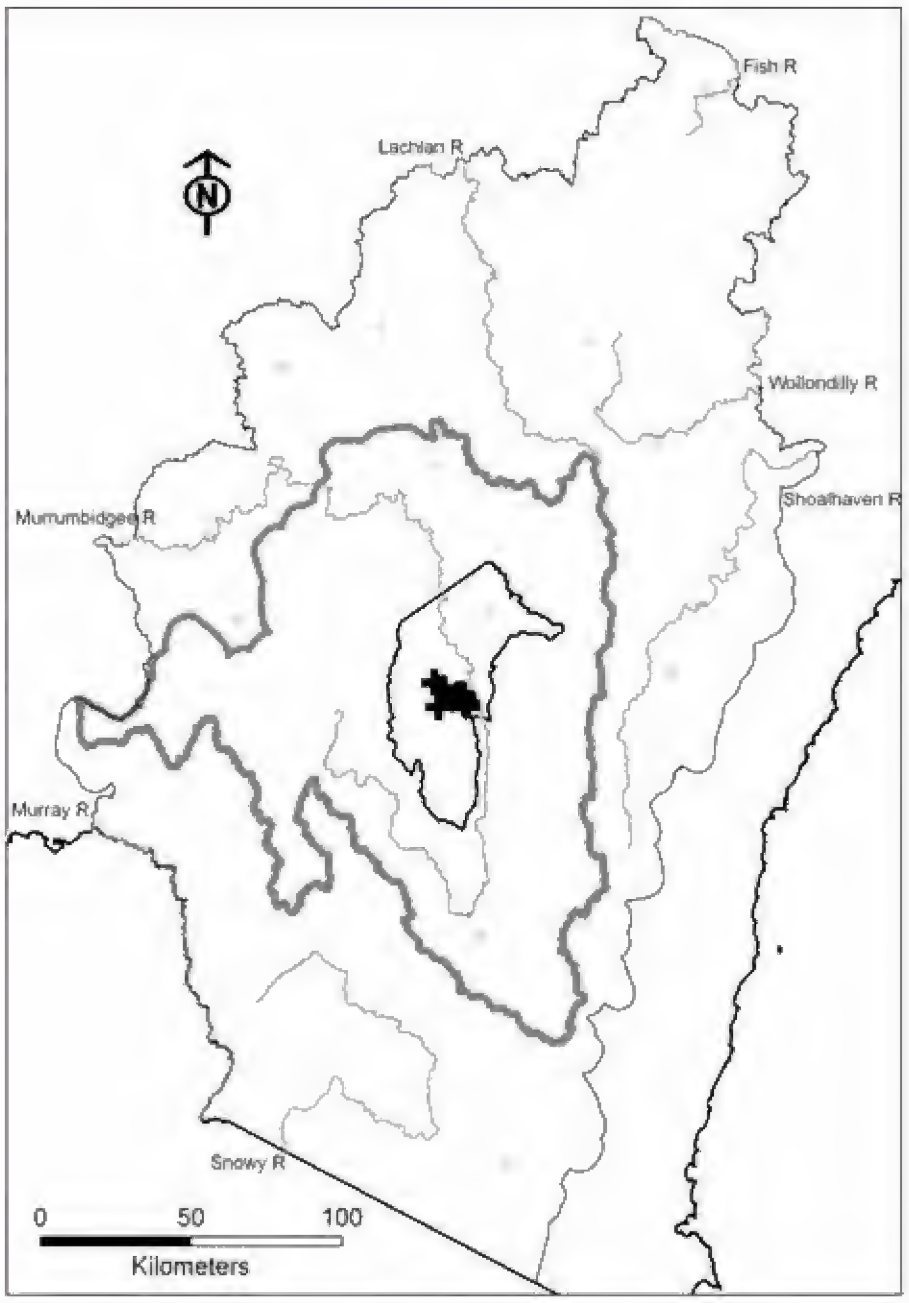

Fig. u18: Distribution of field samples assigned to this community.

Wahlenbergia stricta	2	65	1	18	P
Dianella revoluta	2	41	1	22	C
Glycine clandestina	1	59	1	29	C
Gonocarpus tetragynus	2	71	2	48	C
Hydrocotyle laxiflora	2	53	2	30	C
Hypericum gramineum	1	53	1	25	C
Lomandra longifolia	1	53	2	42	C

Threatened communities: Nil.

Equivalent vegetation types: This community has affinities with Community VG79 [*Montane Dry Shrub/Tussock Grass Forest*] (Gellie (2005).

Frequently occurring weeds: This community is largely confined to the conservation reserve system and has not experienced significant weed invasion. The weeds *Hypochaeris glabra* (0.41) and *Hypochaeris radicata* (0.76) are common, although not abundant within this community.

Threats: This community appears to be well reserved within the ACT, and is unlikely to have been significantly cleared in the past. Given the tenure on which it occurs, future significant clearing is unlikely. Minor threats include herbaceous weed invasion and grazing by feral goats.

Reservation status: All known examples of this community occur in Namadgi NP, however there may be other examples on unsampled private land in surrounding areas.

Extent of clearing: Given its landscape position and its high reservation status, clearing rates in this plant community are likely to be low.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u21: Broad-leaved Peppermint – Candlebark tall dry sclerophyll open forest of quartz-rich ranges of the upper South East Highlands and lower Australian Alps bioregions

Scientific Name: *Eucalyptus dives – Eucalyptus rubida / Acacia dealbata / Hibbertia obtusifolia – Brachyloma daphnoides – Bossiaea buxifolia / Rytidosperma pallidum – Gonocarpus tetragynus – Poa sieberiana*

Number of samples:	45
Richness [mean (±SD)]:	33 (9)
Slope (degrees):	(2) 8–14 (29)
Altitude (m asl):	(745) 909–1074 (1189)
Ave. Annual Rainfall (mm):	(574) 667–764 (900)
Temp. Annual Range (°C):	(24.5) 25.5–26.2 (26.6)

Vegetation Description: Community u21 is a tall eucalypt woodland to open forest to woodland, with a canopy dominated by *Eucalyptus dives* and/or *Eucalyptus rubida*, often with *Eucalyptus bridgesiana* co-occuring. *Eucalyptus rubida* tends to be the most prevalent tree species in this community in the ACT. There may be a scattered to patchy stratum of tall shrubs, commonly including *Acacia dealbata*, *Cassinia longifolia* and/or *Acacia rubida*. A sparse groundlayer is dominated by a mix of low shrubs such as *Hibbertia obtusifolia*, *Brachyloma daphnoides*, *Bossiaea buxifolia*, *Pultenaea procumbens* and *Melichrus urceolatus*, forbs including *Gonocarpus tetragynus*, *Dianella revoluta*, *Hypericum gramineum*, and *Lomandra longifolia* and tussock grasses such as *Rytidosperma pallidum* and *Poa sieberiana.*

This community is widely distributed in the higher parts of the South East Corner bioregion and lower slopes of the Australian Alps bioregion. In the east, it occurs from Captains Flat south through Tinderry, Strike-a-Light and Mount Dowling NRs to Numeralla and Sunny Corner. The community is absent from the southern Monaro basalts but reappears on the ranges in the far south from Merriangaah and Tombong, west to Byadbo and the Suggan Buggan Range. In the north-west, plots run from northeast Namadgi NP (lower slopes of Booroomba Creek) south along Boboyan Road to the lower slopes of Yaouk Bill Range and Murrumbucca.

Within this range, Community u21 generally occurs on broad ridge crests and broad gentle slopes with moderately-low fertility soils of intermediate depth, with records primarily from Adaminaby Group and Yalmy Group sediments (sandstones, mudstones, shales) and from granites and granodiorites (including Shannons Flat Suite, Clear Range Suite and Glenbog Suite). In the east of its range, it may grade into Community m51 [*Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll open forest on exposed quartz-rich slopes and ridges at primarily in the Monaro and Kybeyan – Gourock subregions of the South Eastern Highlands*] on shallower soils on dry, exposed north and west-facing slopes and ridges, while in sheltered gullies and on sheltered south-facing slopes it may be replaced by Community m31 [*Ribbon Gum – Snow Gum – Cassinia longifolia tall shrub-grass open forest of gullies in quartz-rich ranges in the Monaro and Kybeyan-Gourock subregions of the South Eastern Highlands bioregion*]. In the western part of its range it tends to grade into Community u29 [*Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of the South Eastern Highlands bioregion*] on steep exposed slopes with shallower soil or Community u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and northern Australian Alps bioregions*] on moist sheltered slopes and gullies. In frost hollows at higher elevations it may be replaced by Community u27 [*Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia dealbata	1	60	2	25	P
Acacia gunnii	1	22	1	6	P
Acacia rubida	2	36	1	6	P
Astroloma humifusum	1	24	1	5	P
Bossiaea buxifolia	1	64	1	6	P
Brachyloma daphnoides	1	73	1	16	P
Cassinia longifolia	1	62	1	16	P
Dichelachne rara	1	27	1	8	P
Dillwynia sericea	1	24	1	4	P
Eucalyptus bridgesiana	3	38	3	7	P
Eucalyptus dives	3	89	3	17	P
Eucalyptus rubida	3	82	3	8	P
Galium gaudichaudii	1	31	1	9	P
Gonocarpus tetragynus	2	80	2	47	P
Hibbertia obtusifolia	2	96	1	34	P
Hovea heterophylla	1	20	1	4	P
Hovea linearis	1	53	1	13	P
Hypericum gramineum	1	56	1	25	P
Indigofera australis	1	22	1	7	P
Leucopogon fletcheri subsp. *brevisepalus*	1	40	1	3	P
Lomandra multiflora	1	49	1	18	P
Melichrus urceolatus	1	58	1	12	P
Mirbelia oxylobioides	3	18	1	3	P
Pimelea curviflora	1	38	1	6	P
Pultenaea procumbens	2	53	1	4	P
Rytidosperma pallidum	2	84	2	17	P
Rytidosperma spp.	1	22	1	7	P
Stackhousia monogyna	1	36	1	12	P
Wahlenbergia communis	1	22	1	5	P
Wahlenbergia spp.	1	18	1	5	P
Wahlenbergia stricta	1	42	1	18	P
Lomandra longifolia	1	44	2	42	C
Poa sieberiana	1	60	2	48	C

Plate u21: Community u21 showing *Eucalyptus rubida* with patches of *Bursaria spinosa* and *Cassinia longifolia*, and regenerating eucalypts in open grassy patches. Southern end of Bushfords Flats, Mt. Tennent Fire Trail, Namadgi NP.

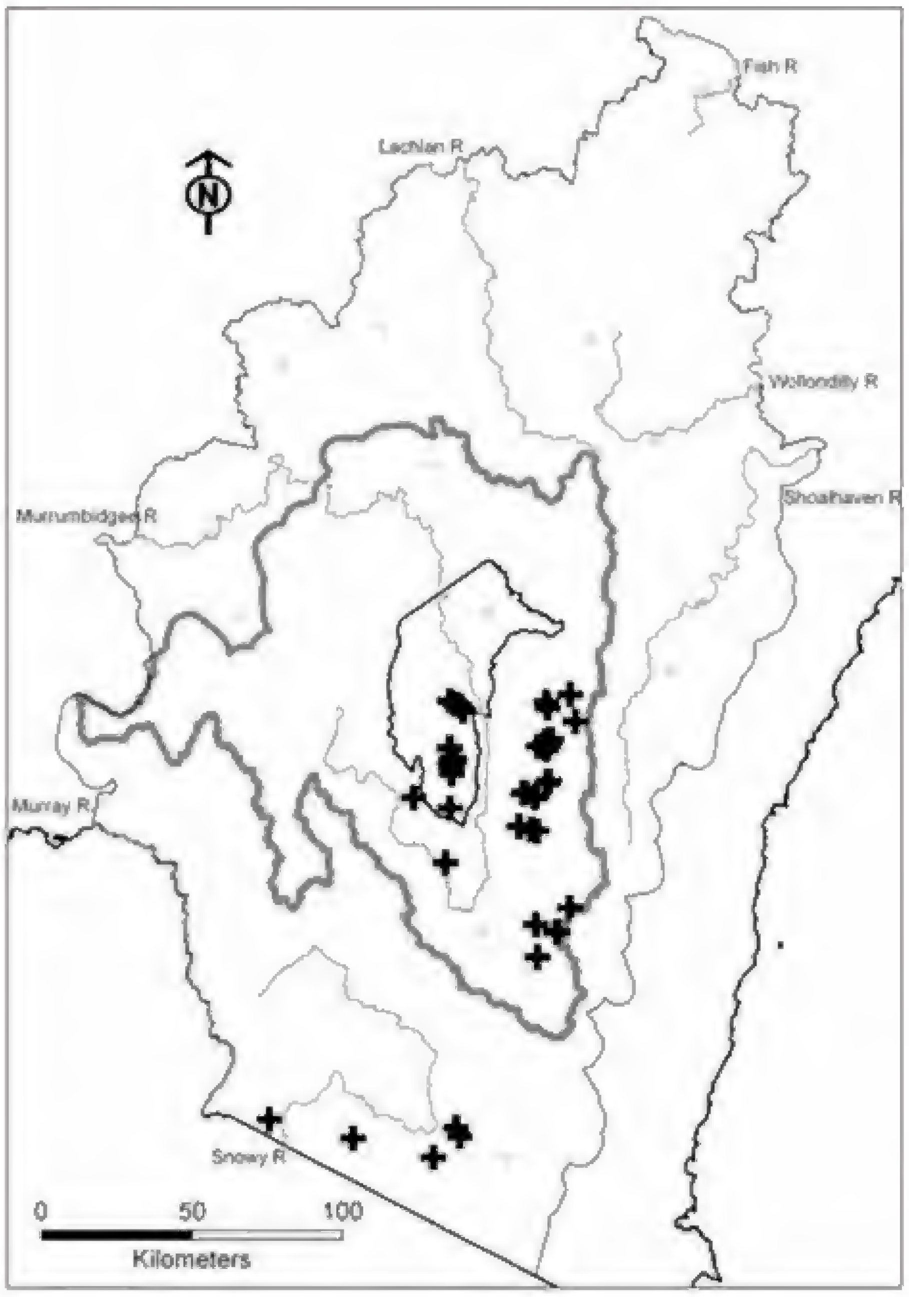

Fig. u21: Distribution of field samples assigned to this community.

Threatened communities: Examples may be part of the TSC Act – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: Community u21 has no directly equivalent community in the classification of Gellie (2005). Most of the plots defining this community were not classified by Gellie (2005), and the small number of common plots were assigned in that classification to either VG74 [*South Eastern Tablelands Dry Shrub/Grass/Herb Forest*] or VG75 [*Tablelands Shrub/Tussock Grass Forest*]. Other plots which defined VG74 and VG75 were assigned by the present study to related groups m31 and m51.

Frequently occurring weeds: Weeds do not feature prominantly in this community, although the common pasture weeds *Centaurium erythraea* and *Hypochaeris radicata* are present in a high proportion of sites (0.43).

Threats: The habitat of this community is generally not attractive to agricultural development, and it is unlikely to have been widely cleared. Where this community occurs on freehold land, incidental clearing for firewood and fenceposts represents a minor threat, as does grazing by feral herbivores.

Reservation status: NSW reserves known to contain this type include Yanununbeyan SCA, Tinderry NR, Burnt School NR, Strike–a–Light NR, Yaouk NR, Numeralla NR, Kybeyan NR, Merriangah NR, Meringo NR, Quidong NR, and south-eastern Kosciuszko NP. Within the ACT, samples of this community are distributed through eastern Namadgi NP.

Extent of clearing: Where the community occurs on relatively fertile soil, it is likely that moderate levels of clearing have occurred for pastoral development.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u29: Apple Box – Broad-leaved Peppermint tall shrub-grass open forest primarily on granitoids of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus bridgesiana – Eucalyptus dives ± Eucalyptus nortonii – Eucalyptus melliodora / Bursaria spinosa – Cassinia longifolia / Elymus scaber – Poa sieberiana – Gonocarpus tetragynus*

Number of samples:	52
Richness [mean (±SD)]:	40 (9)
Slope (degrees):	(0) 12–23 (37)
Altitude (m asl):	(634) 765–961 (1257)
Ave. Annual Rainfall (mm):	(554) 663–778 (945)
Temp. Annual Range (°C):	(24.7) 25.8–26.7 (27.2)

Vegetation Description: Community u29 is a tall eucalypt woodland to open forest characterised by the presence of *Eucalyptus bridgesiana*, *Eucalyptus dives*, *Eucalyptus nortonii* and/or *Eucalyptus melliodora* on granite hills with a shrubby/grassy/herbaceous understorey. Shrub species include *Cassinia longifolia*, *Bursaria spinosa* and *Acacia dealbata*. The groundlayer is herbaceous with the main grass species being *Poa sieberiana*, *Elymus scaber* and *Themeda australis* and forbs including *Hydrocotyle laxiflora*, *Gonocarpus tetragynus*, *Glycine clandestina*, *Hypericum gramineum*, *Desmodium varians*, *Geranium solanderi*, *Galium gaudichaudii* and *Plantago varia*. The dominant tree species may vary from site to site.

This community occurs primarily on granitoids in eastern parts of the Namadgi region (e.g. Booth Range), extending southward to the Snowy Mountains in Kosciuzsko NP, around Merriangaah NR and Puapong, and east to Captains Flat. In the ACT and adjacent ranges it occurs in a mosaic with Community u21 [*Broad-leaved Peppermint – Candlebark tall dry sclerophyll open forest of quartz-rich ranges of the upper South East Highlands and lower Australian Alps bioregions*], and grades downslope into Community u27 [*Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	1	56	2	25	P
Acaena ovina	1	54	1	7	P
Acrotriche serrulata	1	37	1	11	P
Ajuga australis	1	21	1	8	P
Asperula conferta	1	42	1	10	P
Asplenium flabellifolium	1	29	1	8	P
Austrostipa scabra	2	13	1	4	P
Bossiaea buxifolia	1	21	1	7	P
Bothriochloa macra	1	27	1	3	P
Brachyscome rigidula	1	17	1	2	P
Bursaria spinosa	2	85	1	9	P
Carex inversa	1	46	1	8	P
Cassinia longifolia	3	81	1	15	P
Cheilanthes sieberi	2	40	1	8	P
Chrysocephalum semipapposum	1	17	1	4	P
Clematis leptophylla	2	17	1	1	P
Crassula sieberiana	1	33	1	5	P
Cullen microcephalum	1	19	1	2	P
Cymbonotus lawsonianus	1	15	1	5	P
Cymbonotus spp.	2	54	1	3	P
Cynoglossum australe	1	21	1	4	P
Cynoglossum suaveolens	1	13	1	3	P
Daucus glochidiatus	1	54	1	7	P
Desmodium varians	1	69	1	11	P
Dichelachne micrantha	1	37	1	9	P
Dichelachne spp.	1	19	1	2	P
Dodonaea viscosa	1	38	1	2	P
Echinopogon cheelii	1	13	1	<1	P
Echinopogon spp.	1	17	1	<1	P
Elymus scaber	3	87	1	20	P
Epilobium billardierianum subsp. *billardierianum*	1	13	1	2	P
Eucalyptus bridgesiana	3	62	3	6	P
Eucalyptus dives	3	42	3	18	P
Eucalyptus melliodora	3	31	3	5	P
Eucalyptus nortonii	3	38	3	3	P
Euchiton sphaericus	1	58	1	6	P
Galium gaudichaudii	1	63	1	9	P
Geranium solanderi	2	56	1	19	P
Glycine clandestina	2	81	1	29	P
Gonocarpus tetragynus	2	77	2	47	P
Hydrocotyle laxiflora	3	94	2	29	P
Hypericum gramineum	1	73	1	25	P
Indigofera australis	1	25	1	7	P
Kunzea ericoides	3	19	2	4	P
Lepidosperma laterale	1	37	1	9	P
Lomandra filiformis subsp. *filiformis*	1	56	1	15	P
Luzula spp.	1	37	1	6	P
Panicum effusum	1	23	1	3	P
Pimelea curviflora	1	19	1	6	P
Plantago varia	1	56	1	10	P
Pleurosorus rutifolius	1	15	1	<1	P
Poa sieberiana	3	90	2	47	P
Rumex brownii	1	37	1	9	P
Rytidosperma penicillatum	1	23	1	3	P
Rytidosperma spp.	2	23	1	7	P
Schoenus apogon	2	48	1	5	P
Senecio quadridentatus	1	23	1	5	P
Solenogyne dominii	1	17	1	3	P
Solenogyne gunnii	1	15	1	5	P

Plate u29: Community u29 with an open canopy of *Eucalyptus bridgesiana*, scattered *Cassinia longifolia* and a grassy understorey of *Austrostipa scabra* and *Panicum effusum*. Plot UMC136, north of Bullenamang Gap, Murrumbucca.

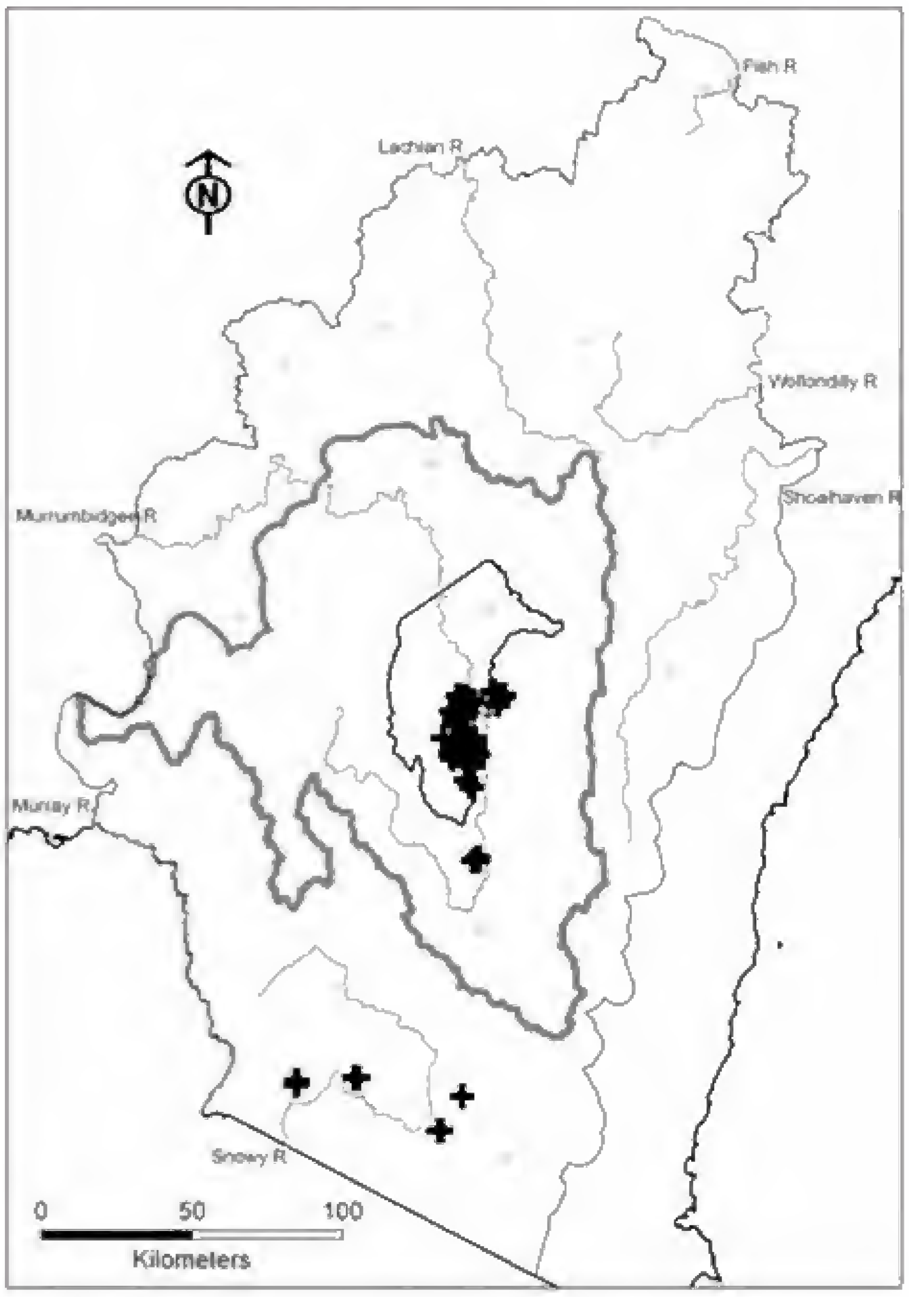

Fig. u29: Distribution of field samples assigned to this community.

Sorghum leiocladum	1	19	1	<1	P
Themeda australis	1	54	2	20	P
Vittadinia cuneata	1	23	1	2	P
Vittadinia muelleri	2	15	1	2	P
Wahlenbergia communis	1	52	1	4	P
Wahlenbergia spp.	1	17	1	5	P
Wahlenbergia stricta	2	48	1	18	P
Hibbertia obtusifolia	1	44	1	35	C
Lomandra longifolia	1	56	2	42	C

Threatened communities: Nil.

Equivalent vegetation types: Nil, although there are some affinities with VG81 [*Eastern Dry Shrub/Herb/Grass Forest*] identified by Gellie (2005).

Frequently occurring weeds: The diverse mix of weeds recorded within the community reflects its distribution over freehold grazing land. The most commonly recorded species are *Centaurium erythraea* (0.62), *Cirsium vulgare* (0.37), *Hypochaeris glabra* (0.25), *Hypochaeris radicata* (0.58), *Lysimachia arvensis* (0.35), *Oxalis corniculata* (0.5), *Petrorhagia nanteuilii* (0.33), *Rosa rubiginosa* (0.42), *Trifolium arvense* (0.63), *Trifolium campestre* (0.46), *Verbascum thapsus* subsp. *thapsus* (0.23).

Threats: Due to its distribution and landscape position, the main threat to this community is likely to be from selective timber removal and grazing by domestic and feral herbivores. Where grazing intensity is not carefully controlled, weed infestation may also occur.

Reservation status: Unknown, although examples of this community are found in Kosciuszko NP, Merriangaah NR, Namadgi NP and Stony Creek NR.

Extent of clearing: Likely to be minor as it occurs on poor soils on hills, although remnants on freehold land may be subject to selective tree removal for on-farm purposes.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u105: Broad-leaved Peppermint – Brittle Gum – Red Stringybark tall shrub-grass dry sclerophyll open forest of lower ranges of the western South Eastern Highlands and upper South Western Slopes bioregions

Scientific Name*:* *Eucalyptus dives – Eucalyptus macrorhyncha – Eucalyptus mannifera / Acacia rubida / Hibbertia obtusifolia – Platylobium montanum – Hardenbergia violacea / Poa sieberiana – Gonocarpus tetragynus – Lomandra longifolia*

Number of samples:	74
Richness [mean (±SD)]:	30 (10)
Slope (degrees):	(0) 11–24 (30)
Altitude (m asl):	(396) 647–861 (1078)
Ave. Annual Rainfall (mm):	(848) 996–1188 (1249)
Temp. Annual Range (°C):	(24.7) 25.2–27.1 (28.3)

Vegetation Description: Community u105 is a tall dry sclerophyll open forest dominated by *Eucalyptus dives*, *Eucalyptus mannifera* and *Eucalyptus macrorhyncha* with a sparse to patchy layer of shrubs including *Acacia rubida* and *Cassinia longifolia*. A diverse complement of low shrubs commonly includes *Hibbertia obtusifolia*, *Monotoca scoparia*, *Platylobium montanum* and/or *Persoonia chamaepeuce*. A groundlayer of tussock grasses, forbs and sprawling twiners, most frequently including *Rytidosperma pallidum*, *Poa sieberiana*, *Dianella revoluta*, *Gonocarpus tetragynus*, *Hardenbergia violacea*, *Hovea linearis*, *Lomandra longifolia* and *Stylidium graminifolium sens. lat.* is typically present.

This community is commonly recorded from dry rocky ridges and exposed west–facing upper slopes with shallow soils of moderate to moderately low fertility derived from a wide variety of substrates including rhyolite, tuff, sandstone, shale, granite, granodiorite, psammite and conglomerate. Plots assigned to this type are closely tied to the Bondo subregion and are distributed around the northern and western rims of the Snowy Mountains, associated with lower foothill ranges, ridges of major valleys and outlying western ridgelines. Plots were recorded from Burrinjuck, Wee Jasper, the margins of the Brindabella Range, the Snubba Range from Wereboldera to Talbingo, east of Talbingo Reservoir on lower slopes above the Tumut River, on the southwestern lower slopes of the Kosciuszko massif from Jagumba Range to Khancoban, Geehi and Tom Groggin, and on outlying lower western ridgelines at Downfall, Carabost, Mundaroo and Tumbarumba. It may also occur in the Cotter River area of the ACT.

Community u105 grades into various communities across its range. In sheltered areas of deeper moister soil such as gullies and footslopes it may be replaced by Community u152 [*Robertson's Peppermint – Red Stringybark very tall grass-forb sheltered open forest of the southwest South Eastern Highlands and upper South Western Slopes bioregions*]. In the north of its range, at higher altitudes it may grade into Community u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*], particularly in the Brindabella ranges, while at lower altitudes and decreasing rainfall from Burrinjuck east it may grade into Community p14 [*Red Stringybark – Scribbly Gum – Rytidosperma pallidum tall grass–shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion*]. To the west as rainfall declines and altitude falls, it is gradually replaced on lower ridgelines by Community u148 [*Red Stringybark – Red Box grass-forb tall open forest of the upper South Western Slopes and western South Eastern Highlands bioregions*].

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia buxifolia	1	14	1	1	P
Acacia gunnii	1	22	1	6	P
Acacia rubida	1	50	1	5	P
Acacia ulicifolia	1	9	1	2	P
Acrotriche serrulata	1	32	1	11	P
Astrotricha ledifolia	1	14	1	<1	P
Austrostipa rudis	1	22	2	3	P
Billardiera scandens	1	30	1	9	P
Boronia nana	1	6	1	<1	P
Cassinia longifolia	1	42	1	16	P
Cassytha pubescens	1	19	1	2	P
Cheiranthera linearis	1	10	1	1	P
Choretrum pauciflorum	1	11	1	3	P
Daviesia leptophylla	1	20	1	5	P
Dianella revoluta	1	65	1	21	P
Dichelachne sieberiana	2	16	2	5	P
Dillwynia phylicoides	2	22	2	2	P
Eriochilus cucullatus	1	9	1	<1	P
Eucalyptus dives	3	86	3	16	P
Eucalyptus globulus subsp. *bicostata*	1	8	3	<1	P
Eucalyptus goniocalyx	3	17	3	4	P
Eucalyptus macrorhyncha	3	76	3	14	P
Eucalyptus mannifera	3	72	3	10	P
Eucalyptus nortonii	2	15	3	3	P
Eucalyptus radiata subsp. *robertsonii*	1	22	3	9	P
Gompholobium huegelii	1	23	1	4	P
Gonocarpus tetragynus	1	89	2	47	P
Grevillea lanigera	1	16	1	3	P
Grevillea ramosissima	2	7	1	<1	P

Hardenbergia violacea	1	72	1	13	P
Hibbertia obtusifolia	1	93	1	33	P
Hovea linearis	1	57	1	12	P
Indigofera australis	1	31	1	6	P
Lepidosperma laterale	1	22	1	9	P
Leptospermum brevipes	1	7	2	<1	P
Leucopogon attenuatus	1	9	1	1	P
Leucopogon fletcheri subsp. *brevisepalus*	1	13	1	3	P
Leucopogon virgatus	1	17	1	3	P
Lomandra filiformis subsp. *coriacea*	1	41	2	18	P
Lomandra filiformis subsp. *filiformis*	1	38	1	16	P
Lomandra longifolia	1	65	2	42	P
Melichrus urceolatus	1	25	1	13	P
Monotoca scoparia	1	58	1	14	P
Omphacomeria acerba	1	8	1	<1	P
Persoonia chamaepeuce	1	50	1	10	P
Pimelea glauca	1	6	1	<1	P
Platylobium montanum	2	65	2	9	P
Poa sieberiana	2	92	2	47	P
Poa tenera	3	10	2	2	P
Pultenaea spinosa	3	23	2	<1	P
Rytidosperma pallidum	2	53	2	17	P
Stackhousia monogyna	1	24	1	12	P
Stylidium graminifolium sens. lat.	1	65	1	24	P
Tetratheca bauerifolia	1	39	1	6	P
Thelymitra pauciflora	1	6	1	<1	P
Xanthorrhoea glauca subsp. *angustifolia*	2	6	2	<1	P

Threatened communities: Nil.

Equivalent vegetation types: This community is defined by a large number of field survey plots, including many plots from forested public lands which were classified by Gellie (2005). Strongly related Forest Ecosystems include VG110 [*Tablelands Dry Shrub/Grass Forest*] (23 plots in common), VG108 [*Western Tablelands Dry Herb/Grass Forest*] (15 plots in common) and VG109 [*Widespread Tablelands Dry Shrub/Tussock Grass Forest*] (5 plots in common). The relationship between Community u105 and communities identified by Benson *et al.* (2010) with similar structural dominants (such as VCA 351) requires resolution through further sampling and analysis.

Frequently occurring weeds: The common pasture weeds *Centaurium erythraea* (0.26) and *Hypochaeris radicata* (0.24) were the most frequently recorded weed species in this community.

Threats: This community is generally found on ridges and steep country which are generally not suitable for agriculture. As a consequence, it is unlikely to have been widely cleared. Examples on private land may be subject to occasional light rough–country grazing, selective tree removal and firewood collection.

Reservation status: Recorded from plots in Burrinjuck NR, Wereboldera SCA, Brindabella NP and SCA, Bimberi NR, Downfall NR, Bogandyera NR and at numerous locations on the western edge of Kosciuszko NP.

Extent of clearing: Unlikely to have been widely cleared.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u105: Community u105, beside Stony Creek firetrail in Wereboldera SCA (near plot SWSWRB05) with *Eucalyptus* dives and *Eucalyptus mannifera* over a diverse layer of tough low shrubs, twiners and grasses.

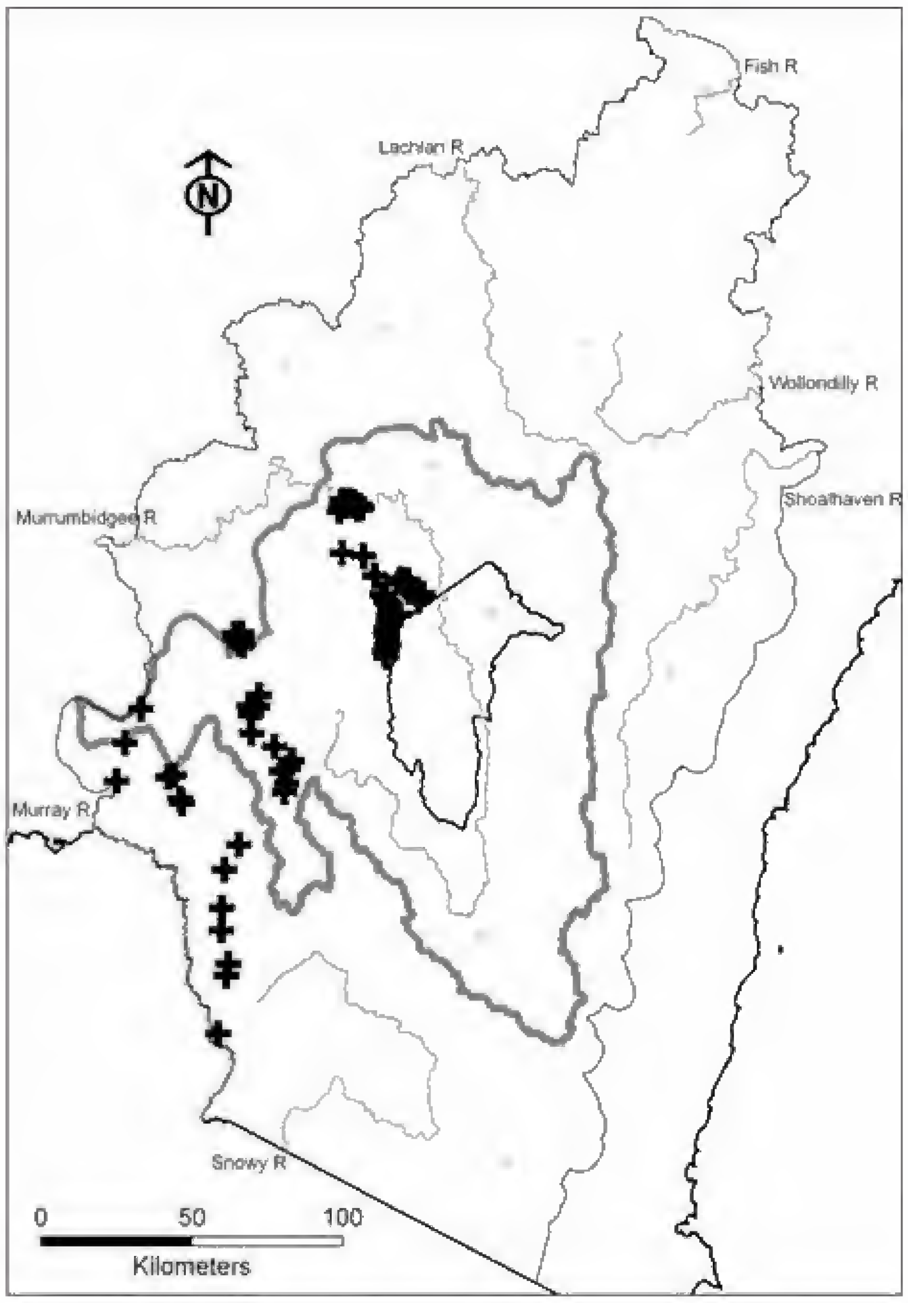

Fig. u105: Distribution of field samples assigned to this community.

u148: Red Stringybark – Red Box grass-forb tall open forest of the upper South Western Slopes and western South Eastern Highlands bioregions

Scientific Name: *Eucalyptus macrorhyncha – Eucalyptus polyanthemos / Hibbertia obtusifolia / Poa sieberiana – Gonocarpus tetragynus – Lomandra filiformis* **subsp.** *coriacea – Hydrocotyle laxiflora – Rytidosperma pilosum – Elymus scaber*

Number of samples:	64
Richness [mean (±SD)]:	32 (9)
Slope (degrees):	(1) 7–19 (30)
Altitude (m asl):	(293) 441–552 (837)
Ave. Annual Rainfall (mm):	(713) 846–961 (1201)
Temp. Annual Range (°C):	(25.5) 26.3–28.2 (28.8)

Vegetation Description: Community u148 is a tall eucalypt forest dominated by *Eucalyptus macrorhyncha* and *Eucalyptus polyanthemos*, occasionally with *Eucalyptus goniocalyx*, *Eucalyptus nortonii* or *Eucalyptus blakelyi*. The shrub layer ranges from sparse to dense, most frequently including *Brachyloma daphnoides*, *Xanthorrhoea glauca* subsp. *angustifolia* and the low shrub *Melichrus urceolatus* within a diverse suite of sclerophyllous shrub taxa occurring across the range of this community. The ground cover is open to dense and dominated by grasses such as *Poa sieberiana*, *Rytidosperma pilosum*, *Elymus scaber* and *Microlaena stipoides*, and forbs including *Gonocarpus tetragynus*, *Hydrocotyle laxiflora*, *Lomandra filiformis* subsp. *coriacea*, *Lomandra filiformis* subsp. *filiformis*, *Daucus glochidiatus* and *Wahlenbergia stricta.*

This community is widely distributed across the western half of the South Eastern Highlands and into the upper Slopes of the NSW South Western Slopes within the Murrumbidgee catchment. It occurs as far east as Yass, and westwards in a band through Tumut and southwards towards the Murray River. It grades into communities such as Community u19 [*Blakely's Red Gum – Yellow Box ± White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands bioregions*] in more fertile areas, Community p14 [*Red Stringybark – Scribbly Gum – Rytidosperma pallidum tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion*] on poorer soils in the north-eastern extent of its range, and Community u105 [*Broad-leaved Peppermint – Brittle Gum – Red Stringybark tall shrub-grass dry sclerophyll open forest of lower ranges of the western South Eastern Highlands and upper South Western Slopes bioregions*] on poorer soils in the western extent of its range.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia buxifolia	1	9	1	1	P
Acacia implexa	1	16	1	2	P
Acacia ulicifolia	2	19	1	1	P
Bothriochloa macra	2	11	1	3	P
Brachychiton populneus	1	17	1	2	P
Brachyloma daphnoides	2	36	1	16	P
Brunonia australis	2	20	1	<1	P
Cassinia longifolia	1	34	1	16	P
Cheilanthes austrotenuifolia	1	17	1	3	P
Cheilanthes sieberi	1	44	1	8	P
Cheiranthera linearis	1	22	1	<1	P
Cynoglossum suaveolens	1	11	1	3	P
Daucus glochidiatus	1	56	1	7	P
Dichelachne crinita	2	13	1	3	P
Dichelachne hirtella	2	16	1	1	P
Dichelachne sieberiana	2	30	2	5	P
Dodonaea viscosa	1	11	1	2	P
Drosera auriculata	1	22	1	2	P
Elymus scaber	2	53	1	20	P
Eucalyptus albens	3	9	3	<1	P
Eucalyptus blakelyi	2	25	3	2	P
Eucalyptus goniocalyx	3	41	3	3	P
Eucalyptus macrorhyncha	3	92	3	14	P
Eucalyptus nortonii	3	30	3	3	P
Eucalyptus polyanthemos	3	67	3	2	P
Eucalyptus sideroxylon	3	11	2	<1	P
Geranium solanderi	1	41	1	19	P
Glycine clandestina	1	52	1	29	P
Gonocarpus tetragynus	2	77	2	47	P
Hibbertia obtusifolia	1	67	1	34	P
Hydrocotyle laxiflora	2	64	2	29	P
Hypericum gramineum	1	45	1	25	P
Lomandra filiformis subsp. *coriacea*	2	63	2	18	P
Lomandra filiformis subsp. *filiformis*	2	66	1	15	P
Lomandra spp.	2	11	1	<1	P
Luzula densiflora	1	31	1	5	P
Melichrus urceolatus	1	27	1	13	P
Microtis unifolia	1	25	1	4	P
Oxalis perennans	1	41	1	13	P
Poa sieberiana	2	72	2	48	P
Pultenaea spinosa	2	17	2	<1	P
Rytidosperma pilosum	2	56	2	8	P
Scutellaria humilis	1	17	1	1	P
Senecio bathurstianus	1	27	1	<1	P
Senecio prenanthoides	1	38	1	19	P
Senecio quadridentatus	1	17	1	5	P
Senecio tenuiflorus	1	20	1	2	P
Stypandra glauca	2	42	2	5	P
Thelymitra spp.	1	11	1	3	P
Tricoryne elatior	1	25	1	3	P
Wahlenbergia stricta	1	61	1	18	P
Wurmbea dioica	1	23	1	2	P
Xanthorrhoea glauca subsp. *angustifolia*	2	27	2	<1	P
Microlaena stipoides	2	47	2	34	C

Threatened communities: Nil.

Equivalent vegetation types: No clear equivalent, but has similarities with VG119 [*Western Tablelands Dry Shrub/Grass Forest*] defined by Gellie (2005). It also displays characteristics of VCA 290 [*Red Stringybark – Red Box – Long-leaved Box – Inland Scribbly Gum tussock grass-shrub low open forest on hills in the southern part of the NSW South-western Slopes bioregion*] (Benson *et al.* 2010) and probably represents the more fertile end of this community.

Frequently occurring weeds: This community is characterised by an abundance of weed species, reflecting its distribution on freehold land, and the effect of domestic stock grazing on the groundlayer. The most commonly recorded weed species are *Aira elegantissima* (0.31), *Briza maxima* (0.86), *Briza minor* (0.45), *Cirsium vulgare* (0.31), *Hypericum perforatum* (0.37), *Hypochaeris glabra* (0.37), *Hypochaeris radicata* (0.55), *Lysimachia arvensis* (0.33), *Orobanche minor* (0.35), *Petrorhagia nanteuilii* (0.51), *Trifolium angustifolium* (0.45), *Trifolium arvense* (0.45) and *Trifolium campestre* (0.41).

Threats: The biggest threat to this community is weed infestation and grazing, which often occur in unison. Clearing is unlikely to represent a significant threat, although selective tree removal does occur, which may induce changes to structure and species composition.

Reservation status: Examples of this community are found in Bango NR, Bogandyera NR, Burrinjuck NR, Downfall NR, Ellerslie NR, Kosciuszko NP, Minjary NP, Mudjarn NR, Mulligans Flat NR, Mundoonen NR, Oak Creek NR, Tumblong SCA and Wereboldera SCA.

Plate u148: Community u148, in crown reserve above Lake Burrinjuck approximately 2.5km north of Taemas Bridge, plot UMC216.

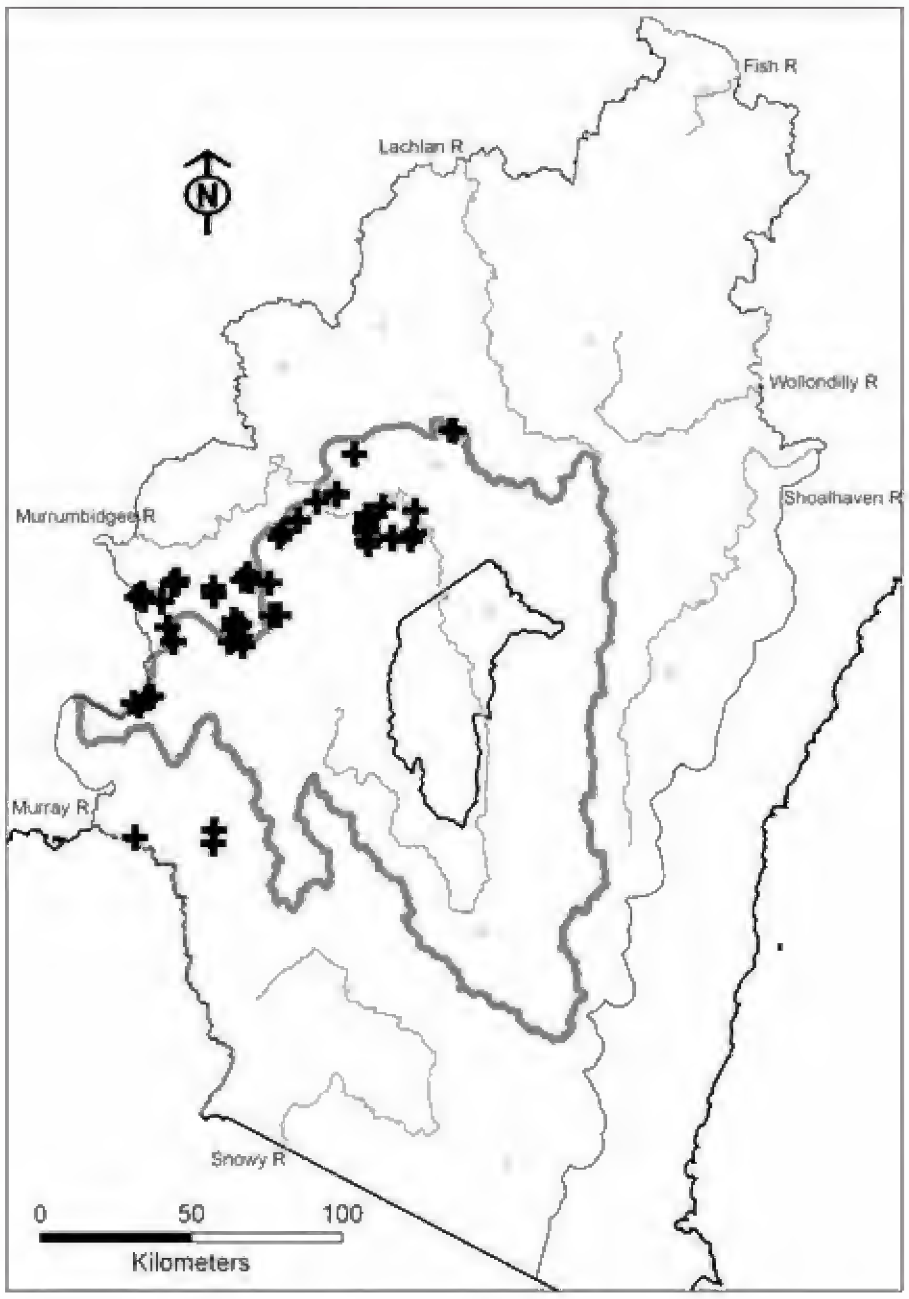

Fig. u148: Distribution of field samples assigned to this community.

Extent of clearing: Likely to be moderate.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u150: Broad-leaved Peppermint – Mountain Gum shrubby tall open forest of the South Eastern Highlands and Australian Alps bioregions

Scientific Name: *Eucalyptus dives – Eucalyptus dalrympleana / Acacia dealbata / Daviesia mimosoides* subsp. *mimosoides – Hibbertia obtusifolia – Monotoca scoparia – Persoonia chamaepeuce – Tetratheca bauerifolia / Lomandra longifolia – Gonocarpus tetragynus – Poa sieberiana*

Number of samples:	73
Richness [mean (±SD)]:	24 (6)
Slope (degrees):	(1) 6–17 (37)
Altitude (m asl):	(826) 1072–1230 (1490)
Ave. Annual Rainfall (mm):	(690) 870–1054 (1181)
Temp. Annual Range (°C):	(23.1) 24.3–25.2 (25.6)

Vegetation Description: Community u150 is a shrubby tall dry open forest dominated by *Eucalyptus dives* and *Eucalyptus dalrympleana*. The well defined midstorey typically includes *Monotoca scoparia*, *Daviesia mimosoides* subsp. *mimosoides* and *Acacia dealbata.* Shorter shrubs often include *Hibbertia obtusifolia*, *Persoonia chamaepeuce*, *Tetratheca bauerifolia* and *Brachyloma daphnoides*. The sparse groundlayer generally includes *Lomandra longifolia*, *Gonocarpus tetragynus*, *Stylidium graminifolium sens. lat.*, *Poa sieberiana*, *Dianella revoluta*, *Goodenia hederacea* subsp. *hederacea*, *Hovea linearis*, *Rytidosperma pallidum*, *Poranthera microphylla* and *Stellaria pungens*.

This is a widespread community, occurring from Tallaganda NP and Kybean SCA in the eastern part of the study area, through Tinderry NR, Namadgi NP to Brindabella NP in the west. It is most common on metasedimentary and granite geologies, usually on lower slopes. This community often forms a mosaic with other dry montane forests and subalpine woodlands including Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*], Community u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and northern Australian Alps bioregions*] and, in the south of the study area, Community m31 [*Ribbon Gum – Snow Gum – Cassinia longifolia tall shrub-grass open forest of gullies in quartz-rich ranges in the Monaro and Kybeyan-Gourock subregions of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia gunnii	1	19	1	6	P
Acrotriche serrulata	1	25	1	11	P
Brachyloma daphnoides	1	49	1	16	P
Cassytha pubescens	1	8	1	2	P
Choretrum pauciflorum	1	25	1	2	P
Daviesia mimosoides subsp. *mimosoides*	3	68	2	8	P
Daviesia ulicifolia	2	29	2	10	P
Deyeuxia quadriseta	1	19	1	4	P
Dianella revoluta	1	51	1	22	P
Eucalyptus dalrympleana	3	67	3	19	P
Eucalyptus dives	3	85	3	17	P
Eucalyptus radiata subsp. *robertsonii*	3	21	3	9	P
Eucalyptus rubida	3	25	3	8	P
Exocarpos strictus	1	30	1	12	P
Gonocarpus tetragynus	2	77	2	47	P
Grevillea lanigera	1	15	1	3	P
Hibbertia obtusifolia	2	93	1	33	P
Hovea linearis	1	48	1	12	P
Lomandra longifolia	2	92	2	41	P
Monotoca scoparia	2	79	1	13	P
Oxylobium ellipticum	1	16	1	4	P
Persoonia chamaepeuce	1	63	1	10	P
Persoonia silvatica	1	11	1	3	P
Pimelea linifolia	1	19	1	8	P
Poa sieberiana	2	70	2	48	P
Stylidium graminifolium sens. lat.	1	71	1	24	P
Tetratheca bauerifolia	2	55	1	6	P
Veronica perfoliata	1	22	1	4	P
Acacia dealbata	2	41	2	26	C

Threatened communities: Nil.

Equivalent vegetation types: Amalgamates VG103 [*Western Montane Dry Fern/Grass Forest*], VG105 [*ACT Montane Dry Shrub Forest*] and VG107 [*Central Tableland/ACT Montane Dry Shrub Forest*], which are very closely related Vegetation Groups previously described by Gellie (2005).

Frequently occurring weeds: The low abundance of weed species reflects the landuse history and current tenure of this community. Only the most dispersive and widespread weed species were recorded, such as *Centaurium erythraea* (0.08) and *Hypochaeris radicata* (0.17).

Threats: Frequent and intense fire has the potential to affect the structural and floristic integrity of this vegetation community. The naturally open midstorey and canopy may make this community attractive to grazing by feral herbivores.

Reservation status: Likely to be reasonably well reserved; most of the plots assigned to this community were located in conservation reserves, including Namadgi NP, Bimberi NR, Bondi Gulf NR, Brindabella NP and SCA, Dangelong NR, Nimmo NR, Scabby Range NR, Tallaganda NP, Tinderry NR, Yanununbeyan NP and Yaouk NR.

Extent of clearing: Not assessed, but likely to be minimal.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u150: Community u150 dominated by *Eucalyptus dalrympleana* with sparse *Eucalyptus pauciflora* and a shrubby understorey of *Daviesia mimosoides*. Coolumbooka NR near Bombala.

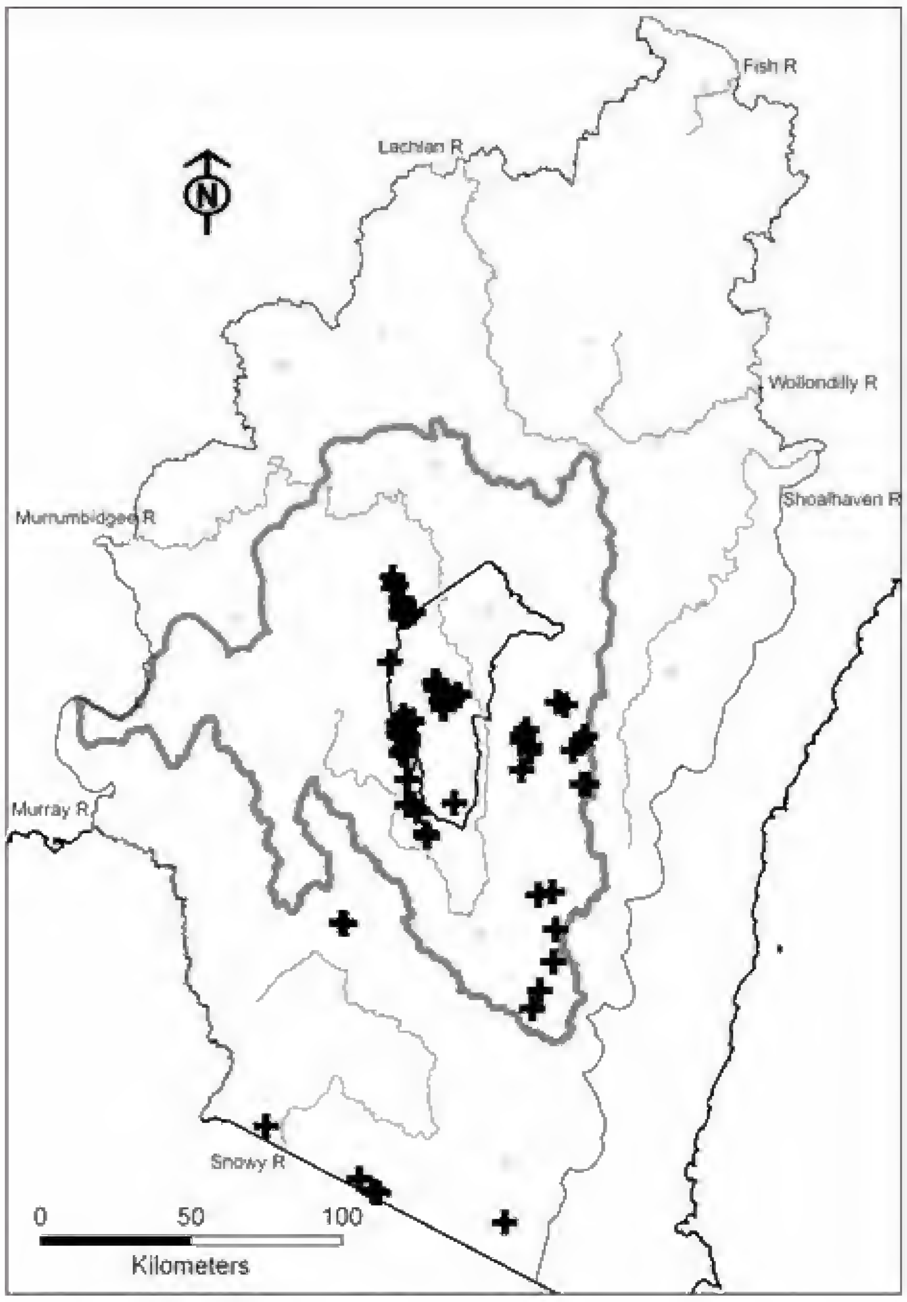

Fig. u150: Distribution of field samples assigned to this community.

u152: Robertson's Peppermint – Red Stringybark very tall grass-forb sheltered open forest of the southwest South Eastern Highlands and upper South Western Slopes bioregions

Scientific Name: *Eucalyptus radiata* subsp. *robertsonii – Eucalyptus macrorhyncha / Acacia dealbata / Pteridium esculentum – Hibbertia obtusifolia / Poa sieberiana – Microlaena stipoides – Hydrocotyle laxiflora – Gonocarpus tetragynus – Geranium solanderi – Acaena novae–zelandiae*

Number of samples: 101
Richness [mean (±SD)]: 44 (12)
Slope (degrees): (1) 5–17 (38)
Altitude (m asl): (309) 619–817 (1085)
Ave. Annual Rainfall (mm): (825) 963–1177 (1312)
Temp. Annual Range (°C): (24.5) 25.8–27.5 (28.6)

Vegetation Description: Community u152 is a very tall open eucalypt forest with canopy commonly dominated by *Eucalyptus radiata* subsp. *robertsonii* and *Eucalyptus macrorhyncha*, less frequently with *Eucalyptus bridgesiana*, *Eucalyptus dives* or *Eucalyptus viminalis*. Patches within this community may be dominated by *Eucalyptus globulus* subsp. *bicostata*. Plots assigned to this group commonly contains a sparse layer of scattered shrubs and small trees including *Acacia dealbata* and *Acacia melanoxylon*, with a patchy to continuous groundlayer of grasses including *Poa sieberiana*, *Microlaena stipoides*, *Elymus scaber* and *Themeda australis,* the fern *Pteridium esculentum* and a diverse mix of forbs including *Acaena novae-zelandiae*, *Dichondra repens*, *Euchiton japonicus*, *Geranium solanderi*, *Glycine clandestina*, *Gonocarpus tetragynus*, *Hydrocotyle laxiflora*, *Hypericum gramineum*, *Lomandra filiformis* subsp. *filiformis*, *Plantago varia*, *Senecio prenanthoides*, *Viola betonicifolia* and *Wahlenbergia stricta.* Low shrubs such as *Hibbertia obtusifolia* and *Platylobium montanum* are often present.

This community is found on moist sheltered slopes and gullies along lower western margins of the Snowy Mountains and further west on lower outlying ranges. It is commonly recorded from soils of intermediate fertility derived from a wide variety of substrates including granodiorite, granite, rhyolite, sandstone, tuff, psammite and shale. Plots are distributed around the northern and western rims of the Snowy Mountains, associated with lower foothills of the ranges and major valleys and outlying lower western ranges. Records occur from Burrinjuck and lower slopes of the Brindabellas in the north, west and south to Bungongo, Wee Jasper, Billapaloola and Argalong; south along Snubba Range and lower slopes of the upper Goobarragandra and Tumut Rivers; western footslopes of the Bago Range at Courabyra, Tumbarumba and Maragle; to the far south along lower slopes of the upper Murray gorge to Khancoban and Tom Groggin; and on lower ranges to the west including Ellerslie, Downfall and Munderoo.

Community u152 generally occurs on more sheltered slopes and footslopes with somewhat deeper, moister soils than the related Community u105 [*Broad-leaved Peppermint – Brittle Gum – Red Stringybark tall shrub-grass dry sclerophyll open forest of lower ranges of the western South Eastern Highlands and upper South Western Slopes bioregions*]. At higher altitudes with cooler winters and increasing rainfall it may be replaced by Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*] or Community u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and northern Australian Alps bioregions*], while at lower elevations on the margins of undulating slopes country it may grade into Community u148 [*Red Stringybark – Red Box grass-forb tall open forest of the upper South Western Slopes and western South Eastern Highlands bioregions*] or Community u29 [*Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	2	66	2	25	P
Acacia melanoxylon	1	42	1	13	P
Acaena echinata	1	49	1	8	P
Acaena novae-zelandiae	2	73	1	26	P
Acaena ovina	1	5	1	<1	P
Acrotriche serrulata	1	50	1	10	P
Ajuga australis	1	23	1	7	P
Ammobium craspedioides	2	5	1	<1	P
Amyema pendulum	1	13	1	2	P
Asperula conferta	1	29	1	10	P
Asperula scoparia	2	35	2	22	P
Boronia nana	1	9	1	<1	P
Brunonia australis	2	4	2	<1	P
Bulbine bulbosa	1	30	1	3	P
Burchardia umbellata	1	7	1	<1	P
Caladenia carnea	1	19	1	<1	P
Carex breviculmis	2	30	1	12	P
Carex incomitata	1	11	1	<1	P
Cassinia aculeata	1	29	1	13	P
Cassinia longifolia	1	38	1	16	P
Cheilanthes austrotenuifolia	1	11	1	3	P
Chiloglottis trapeziformis	1	6	1	<1	P
Corybas spp.	1	5	1	<1	P
Cymbonotus preissianus	2	47	1	5	P
Cynoglossum suaveolens	1	10	1	3	P
Daucus glochidiatus	1	26	1	8	P
Desmodium varians	1	32	1	12	P
Dichelachne crinita	1	10	1	3	P
Dichelachne sieberiana	2	19	2	5	P
Dichondra repens	2	54	2	20	P
Dipodium roseum	1	13	1	<1	P
Diuris sulphurea	1	7	1	1	P
Drosera auriculata	2	25	1	2	P
Drosera spp.	1	4	1	<1	P
Echinopogon intermedius	1	10	1	<1	P
Echinopogon ovatus	2	41	1	9	P
Elymus scaber	2	56	1	20	P
Epilobium billardierianum subsp. *cinereum*	1	28	1	4	P
Eucalyptus bridgesiana	3	37	3	6	P
Eucalyptus dives	2	34	3	18	P
Eucalyptus globulus subsp. *bicostata*	3	13	1	<1	P
Eucalyptus macrorhyncha	3	60	3	14	P
Eucalyptus radiata subsp. *robertsonii*	3	68	3	7	P
Eucalyptus viminalis	3	24	3	12	P
Euchiton japonicus	1	54	1	14	P
Exocarpos cupressiformis	1	20	1	3	P
Galium ciliare	1	5	2	<1	P
Galium gaudichaudii	1	26	1	9	P
Galium leiocarpum	1	12	1	4	P
Geranium solanderi	2	69	1	18	P
Glossodia major	2	4	1	<1	P
Glycine clandestina	1	82	1	28	P
Gompholobium huegelii	2	13	1	4	P
Gonocarpus tetragynus	2	81	2	47	P
Grevillea rosmarinifolia	1	5	1	<1	P
Hardenbergia violacea	1	26	1	14	P
Hibbertia obtusifolia	1	66	1	34	P
Hovea linearis	1	24	1	13	P
Hydrocotyle laxiflora	2	81	2	28	P
Hypericum gramineum	1	68	1	24	P
Leptospermum continentale	1	10	1	1	P
Lomandra filiformis subsp. *coriacea*	2	38	2	18	P
Lomandra filiformis subsp. *filiformis*	1	59	1	15	P
Luzula densiflora	1	17	1	5	P
Luzula flaccida	1	47	1	12	P
Mentha diemenica	1	17	1	2	P
Microlaena stipoides	2	82	2	33	P

Plate u152: Community u152 on the footslope above Stony Creek, Wereboldera SCA, with *Eucalyptus bridgesiana* and *Eucalyptus macrorhyncha* over a scattered low shrubs and a grassy groundcover.

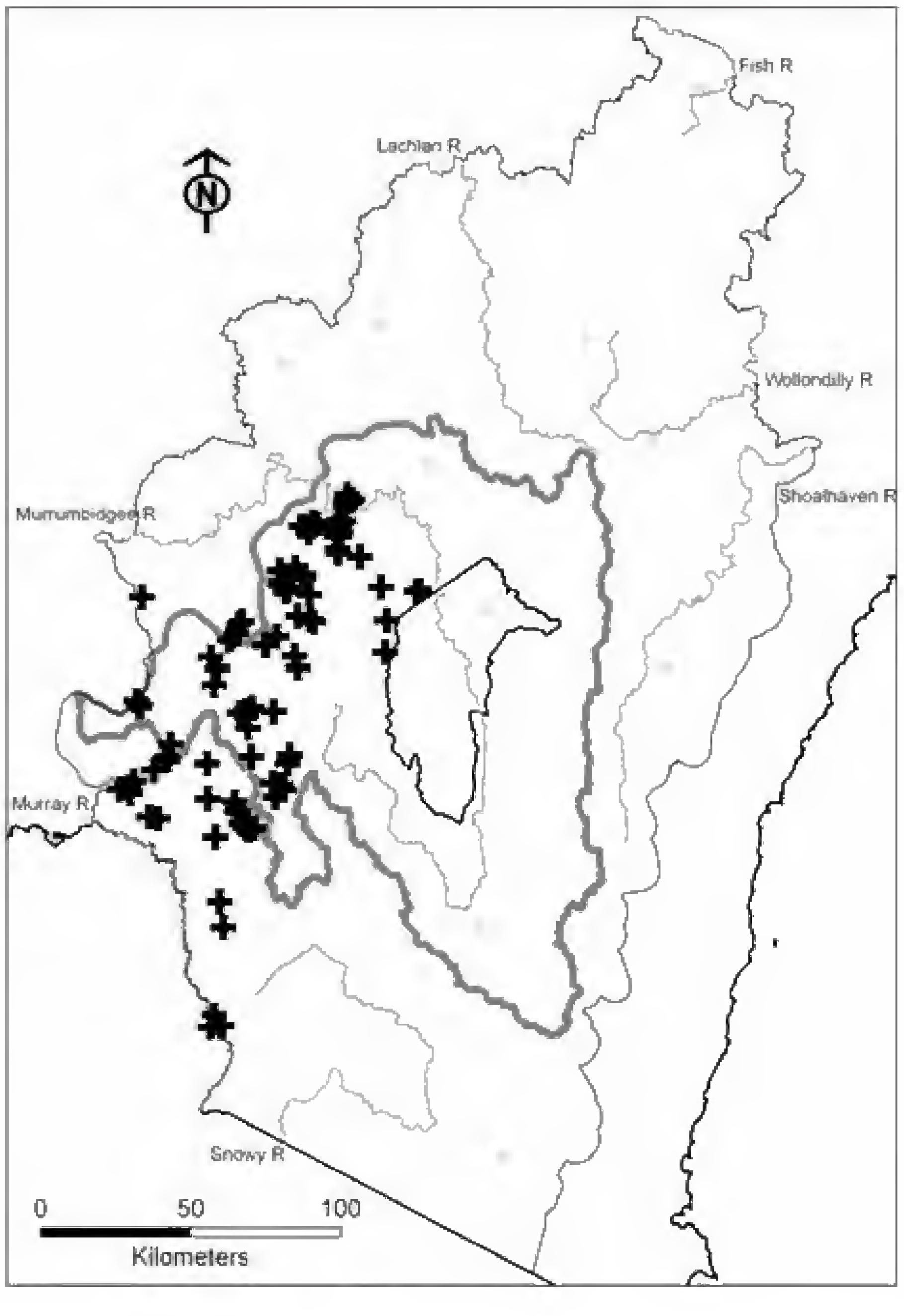

Fig. u152: Distribution of field samples assigned to this community.

Microtis unifolia	1	33	1	3	P
Ophioglossum lusitanicum	2	4	1	<1	P
Oxalis exilis	1	23	1	4	P
Oxalis perennans	1	25	1	13	P
Oxalis radicosa	1	4	1	<1	P
Pimelea curviflora	1	19	1	6	P
Plantago varia	2	55	1	10	P
Platylobium montanum	2	53	2	9	P
Poa helmsii	1	11	2	3	P
Poa sieberiana	3	86	2	47	P
Polygala japonica	1	4	1	<1	P
Pteridium esculentum	2	68	2	26	P
Pterostylis longifolia	1	6	1	<1	P
Pterostylis nutans	1	14	1	<1	P
Pterostylis pedunculata	1	8	1	<1	P
Pultenaea juniperina	2	5	2	<1	P
Pultenaea polifolia	1	5	1	<1	P
Ranunculus lappaceus	1	34	1	10	P
Ranunculus pachycarpus	2	4	0	0	P
Ranunculus scapiger	2	10	1	1	P
Ranunculus sessiliflorus	2	5	1	<1	P
Rytidosperma penicillatum	2	11	1	3	P
Rytidosperma pilosum	2	34	2	8	P
Rytidosperma racemosum	2	28	2	10	P
Scutellaria humilis	1	15	1	1	P
Senecio bathurstianus	1	7	1	1	P
Senecio diaschides	2	23	1	5	P
Senecio prenanthoides	1	54	1	18	P
Senecio tenuiflorus	2	10	1	2	P
Stackhousia monogyna	1	35	1	12	P
Thelymitra pauciflora	1	5	1	<1	P
Themeda australis	2	52	2	20	P
Thysanotus tuberosus	1	14	1	3	P
Veronica calycina	1	45	1	15	P
Viola betonicifolia	2	65	1	26	P
Wahlenbergia stricta	1	52	1	18	P
Wurmbea dioica	1	25	1	2	P
Stellaria pungens	1	41	2	31	C

Threatened communities: Nil.

Equivalent vegetation types: The most strongly related Forest Ecosystems of Gellie (2005) are VG93 [*Western Tablelands Herb/Grass Dry Forest*] (29 shared plots) and VG94 [*South West Slopes Acacia Dry Herb/Grass Forest*] (8 plots). Community u152 has affinities with VCA 295 [*Robertson's Peppermint – Broad-leaved Peppermint – Norton's Box – stringybark shrub-fern open forest of the NSW South Western Slopes and South Eastern Highlands bioregions*] (Benson *et al.* 2010).

Frequently occurring weeds: Although this community is most common on public land (State Forest and Conservation Reserve), its proximity to land used for domestic stock grazing is reflected in the weed species most commonly recorded. These include *Centaurium erythraea* (0.42), *Cirsium vulgare* (0.32), *Hypericum perforatum* (0.31), *Hypochaeris radicata* (0.78), *Rosa rubiginosa* (0.31) and *Hypericum perforatum* (0.30).

Threats: Most surveyed occurrences of this community are on slopes and foothills of steep country with relatively low suitability for agriculture, and these situations are unlikely to have been widely cleared. It is more likely that some clearing has occurred on the margins of private land where gentler footslopes were considered suitable for pasture development and grazing. Areas in State Forests may be subject to logging and to fire regimes associated with silvicultural management, which may modify vegetation structure and floristic composition over time. Surveyed examples have not been subject to widespread weed invasion, but areas subject to disturbance by grazing animals or vehicles, including logged forests, may be more prone to invasion by weeds. This community is found within the altitude and rainfall band prefered by *Hypericum perforatum* – >500m altitude and >600mm rainfall; Naughton & Bourke 2007) and may be prone to invasion by this weed.

Reservation status: Recorded from plots within Burrinjuck NR, Brindabella NP and SCA, Bimberi NR, Wereboldera SCA, Ellerslie NR, Downfall NR, Courabyra NR, Bogandyera NR, Clarkes Hill NR and at numerous locations on the western edge of Kosciuszko NP.

Extent of clearing: In the eastern part of its range (in the foothills of the Kosciuszko main range), this community is unlikely to have been widely cleared. In the western part of its range, where it occurs more often on undulating private land it may have been subject to moderate levels of clearing for pasture development.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Naughton, M. & Bourke, C.A. (2007) Primefact 694 – St John's Wort (*Hypericum perforatum*). NSW Department of Primary Industries, Orange.

u165: Robertson's Peppermint very tall shrubby open forest primarily of the Bondo subregion of the South Eastern Highlands

Scientific Name: *Eucalyptus radiata* subsp. *robertsonii / Platylobium montanum – Hibbertia obtusifolia – Olearia erubescens – Persoonia chamaepeuce – Pteridium esculentum / Lomandra longifolia – Gonocarpus tetragynus – Poa sieberiana*

Number of samples:	23
Richness [mean (±SD)]:	28 (9)
Slope (degrees):	(3) 6–20 (30)
Altitude (m asl):	(497) 751–1032 (1174)
Ave. Annual Rainfall (mm):	(836) 989–1249 (1383)
Temp. Annual Range (°C):	(24.3) 25–26.8 (28.2)

Vegetation Description: Community u165 is a very tall eucalypt open forest dominated by *Eucalyptus radiata* subsp. *robertsonii*, occasionally with other eucalypts including *Eucalyptus dives*, *Eucalyptus dalrympleana* or *Eucalyptus viminalis*. The shrub layer ranges from dense to sparse, with shrubs including *Platylobium montanum*, *Olearia erubescens, Persoonia chamaepeuce*, *Monotoca scoparia*, *Exocarpos strictus* and *Hibbertia obtusifolia*. *Daviesia latifolia* is abundant in recently burnt patches of forest. The ground cover is open to dense and dominated by forbs such as *Lomandra longifolia* and *Gonocarpus tetragynus,* with *Poa sieberiana* being the dominant grass species. The climber *Clematis aristata* is often present.

This community is distributed primarily in western sections of Kosciuszko NP, extending northwards to the Brindabella ranges and south to the Geehi valley in the Murray catchment. It grades into communities such as Community u105 [*Broad–leaved Peppermint – Brittle Gum – Red Stringybark tall shrub-grass dry sclerophyll open forest of lower ranges of the western South Eastern Highlands and upper South Western Slopes bioregions*], Community u239 [*Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions*], Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*] and in the Brindabellas, Community u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and northern Australian Alps bioregions*]. This community may extend further west into the NSW South Western Slopes bioregion.

Plate u165: Community u165 beside the Alpine Way south of Geehi Flat (near plot SZ27011M), with a canopy dominated by *Eucalyptus radiata* subsp. *robertsonii* above patches of *Acacia dealbata* and *Pomaderris lanigera* and a groundcover dominated by *Pteridium esculentum* and *Poa sieberiana*.

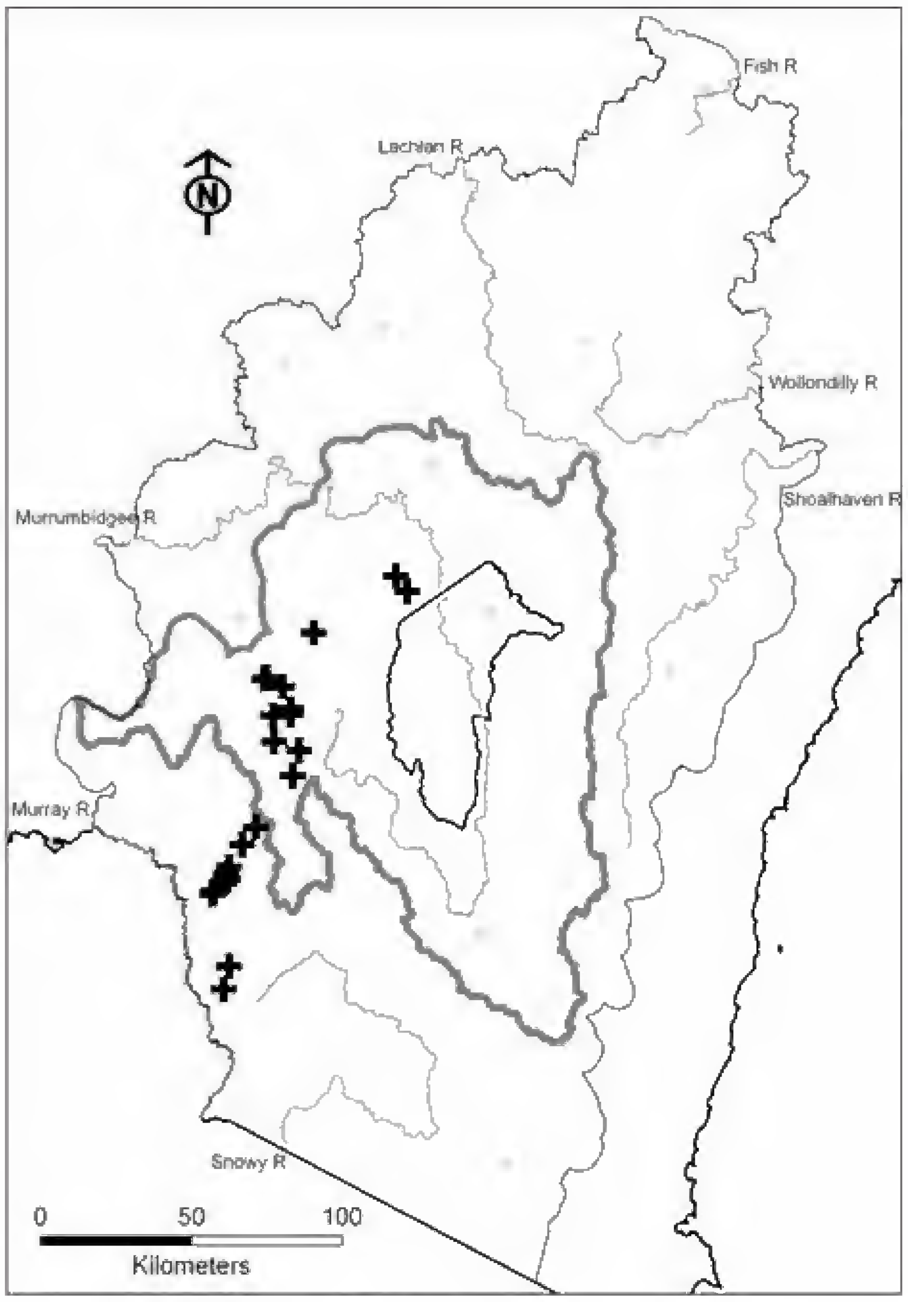

Fig. u165: Distribution of field samples assigned to this community.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia rubida	1	39	1	6	P
Asperula scoparia	1	57	2	22	P
Brachyscome spathulata	1	35	1	11	P
Caladenia gracilis	1	22	1	1	P
Cassinia uncata	2	22	2	1	P
Clematis aristata	1	70	1	23	P
Coprosma hirtella	1	39	1	12	P
Coprosma quadrifida	1	30	1	8	P
Corybas spp.	1	22	1	<1	P
Craspedia jamesii	1	22	1	4	P
Daviesia latifolia	2	39	2	7	P
Eucalyptus radiata subsp. *robertsonii*	3	91	3	8	P
Exocarpos strictus	1	35	1	12	P
Gonocarpus tetragynus	1	83	2	47	P
Hibbertia obtusifolia	1	70	1	34	P
Lomandra longifolia	1	87	2	42	P
Monotoca scoparia	1	48	1	15	P
Olearia erubescens	1	57	1	12	P
Persoonia chamaepeuce	2	52	1	11	P
Pimelea linifolia	1	30	1	8	P
Platylobium montanum	2	96	2	10	P
Pteridium esculentum	2	65	2	27	P
Tetratheca bauerifolia	1	39	1	7	P
Poa sieberiana	2	65	2	48	C
Viola betonicifolia	1	43	1	27	C

Threatened communities: Nil.

Equivalent vegetation types: This community is most similar to VCA 295 [*Robertson's Peppermint – Broad-leaved Peppermint – Norton's Box – stringybark shrub-fern open forest of the NSW South Western Slopes and South Eastern Highlands bioregions*] (Benson *et al*. 2010). It incorporates VG106 [*Montane Dry Shrub/Tussock Forest*] of Gellie (2005)

Frequently occurring weeds: As with many other forested communities, *Hypochaeris radicata* (0.3) is the most frequently recorded species.

Threats: There are few threats to the structure or composition of this community, however a future increase in fire frequency may alter the community structure and floristic composition.

Reservation status: Examples of this community are recorded from Brindabella NP and Kosciuszko NP.

Extent of clearing: Considered likely to be minor, although some areas have been cleared for pastoral land or *Pinus radiata* plantations. Selective logging may also have affected the age-structure of the community in some areas.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u191: Black Cypress Pine – Brittle Gum tall dry open forest on hills primarily in the Cooma region

Scientific Name: *Callitris endlicheri – Eucalyptus mannifera / Bossiaea buxifolia – Cassinia longifolia – Brachyloma daphnoides / Crassula sieberiana – Oxalis perennans – Austrostipa scabra – Chrysocephalum semipapposum*

Number of samples:	14
Richness [mean (±SD)]:	33 (10)
Slope (degrees):	(0) 6–12 (26)
Altitude (m asl):	(652) 805–910 (996)
Ave. Annual Rainfall (mm):	(507) 518–540 (614)
Temp. Annual Range (°C):	(26.3) 26.9–27.5 (27.6)

Vegetation Description: Community u191 is a tall dry open forest to woodland, with a canopy dominated by *Callitris endlicheri* and *Eucalyptus mannifera* and occasional *Eucalyptus viminalis*. The shrub layer is generally sparse and commonly includes *Brachyloma daphnoides*, *Cassinia longifolia* and *Bossiaea buxifolia*, often with dense patches of young *Callitris endlicheri*. Groundlayer vegetation is generally patchy due to high levels of litter or surface rock, with scattered large tussocks of *Rytidosperma pallidum*, and frequent forbs of low cover including *Crassula sieberiana*, *Oxalis perennans*, *Chrysocephalum semipapposum*, *Gonocarpus tetragynus*, grasses including *Austrostipa scabra*, *Rytidosperma* spp. and *Elymus scaber*, the sedge *Carex breviculmis* and the fern *Cheilanthes austrotenuifolia*.

Community u191 primarily occurs on earthy sands and lithosols derived from metasediments in hills around Cooma including Mount Gladstone and Binjura NR, extending north along Clear Range and steep lower slopes above the Murrumbidgee River. It is also recorded from steep slopes of the Molonglo River gorge near Queanbeyan. Around Cooma and Clear Range this community grades into Community m51 [*Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll open forest on exposed quartz–rich slopes and ridges at primarily in the Monaro and Kybeyan – Gourock subregions of the South Eastern Highlands*] and Community u178 [*Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands*] on more fertile soils lines down slope. Around Queanbeyan it grades into Community u66 [*Mealy Bundy – Red Stringybark grass-herb mid-high open forest of the South Eastern Highlands and Upper Slopes Subregion of the South Western Slopes bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia mearnsii	1	36	2	3	P
Aristida ramosa	1	43	2	5	P
Austrostipa densiflora	1	21	1	1	P
Austrostipa scabra	1	79	2	4	P
Bossiaea buxifolia	1	64	1	7	P
Bothriochloa macra	1	29	1	3	P
Brachyloma daphnoides	1	64	1	16	P
Callitris endlicheri	2	86	3	1	P
Carex breviculmis	1	64	1	13	P
Cassinia longifolia	1	64	1	16	P
Cheilanthes austrotenuifolia	1	64	1	3	P
Chrysocephalum apiculatum	1	43	1	6	P
Chrysocephalum semipapposum	1	79	1	4	P
Crassula sieberiana	1	93	1	5	P
Daucus glochidiatus	1	43	1	8	P
Desmodium varians	1	43	1	12	P
Dichelachne spp.	1	21	1	2	P
Einadia nutans	1	36	1	4	P
Elymus scaber	1	71	1	21	P
Eucalyptus mannifera	3	57	3	11	P
Euchiton involucratus	1	64	1	3	P

Grevillea lanigera	1	29	1	3	P
Lissanthe strigosa	1	50	1	7	P
Lomandra filiformis	1	21	1	2	P
Luzula densiflora	1	36	1	6	P
Mirbelia oxylobioides	1	21	1	3	P
Oxalis perennans	1	86	1	13	P
Poa phillipsiana	1	29	3	3	P
Rytidosperma spp.	1	71	1	7	P
Senecio quadridentatus	1	29	1	6	P
Themeda australis	1	57	2	21	P
Vittadinia cuneata	1	36	1	2	P
Vittadinia muelleri	1	21	1	2	P
Wahlenbergia communis	1	29	1	5	P
Wahlenbergia gracilis	1	36	1	6	P
Wahlenbergia stricta	1	57	1	19	P
Xerochrysum viscosum	1	29	1	1	P
Gonocarpus tetragynus	1	71	2	48	C
Hydrocotyle laxiflora	1	43	2	30	C
Poa sieberiana	1	57	2	48	C
Rytidosperma pallidum	3	43	2	18	C

Threatened communities: Nil.

Equivalent vegetation types: This community was identified largely from field survey plots completed for the current study, and there is no equivalent Forest Ecosystem identified by Gellie (2005). It is possibly related to VG79 [*Montane Dry Shrub/Tussock Grass Forest*].

Frequently occurring weeds: This community often contains abundant weed populations, reflecting its susceptibility to over-grazing by domestic, feral or native herbivores. The most commonly recorded species were *Acetosella vulgaris* (0.29), *Echium vulgare* (0.36), *Eragrostis curvula* (0.21), *Erophila verna* (0.64), *Hypericum perforatum* (0.29), *Hypochaeris glabra* (0.29), *Hypochaeris radicata* (0.57), *Linaria arvensis* (0.57), *Lysimachia arvensis* (0.21), *Pentaschistis airoides* (0.43), *Petrorhagia nanteuilii* (0.64), *Trifolium arvense* (0.64) and *Vulpia myuros f. megalura* (0.36).

Threats: Due to the landscape position and infertile soils, the main threat to this community is considered to be over–grazing by domestic, feral or native herbivores. This in turn may facilitate weed invasion. Where the community occurs in close proximity to urban centres, high fire frequency has the potential to impact upon species composition, structure and habitat features such as fallen timber.

Reservation status: This community is sampled from Binjura NR and Molonglo Gorge NR. It is likely to occur in Bullen Range NR and Gigerline NR in the ACT and is known to occur at Scottsdale Reserve (Bush Heritage Australia) north of Bredbo.

Extent of clearing: Likely to be minor as it occurs on low nutrient soils on hills.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u191: *Eucalyptus mannifera* with regenerating and mature *Callitris endlicheri* and a patchy layer of *Rytidosperma pallidum* and leaf litter is characteristic of Community u191, as with this example at plot UMC125, Murrumbidgee gorge in Binjura NR north of Cooma.

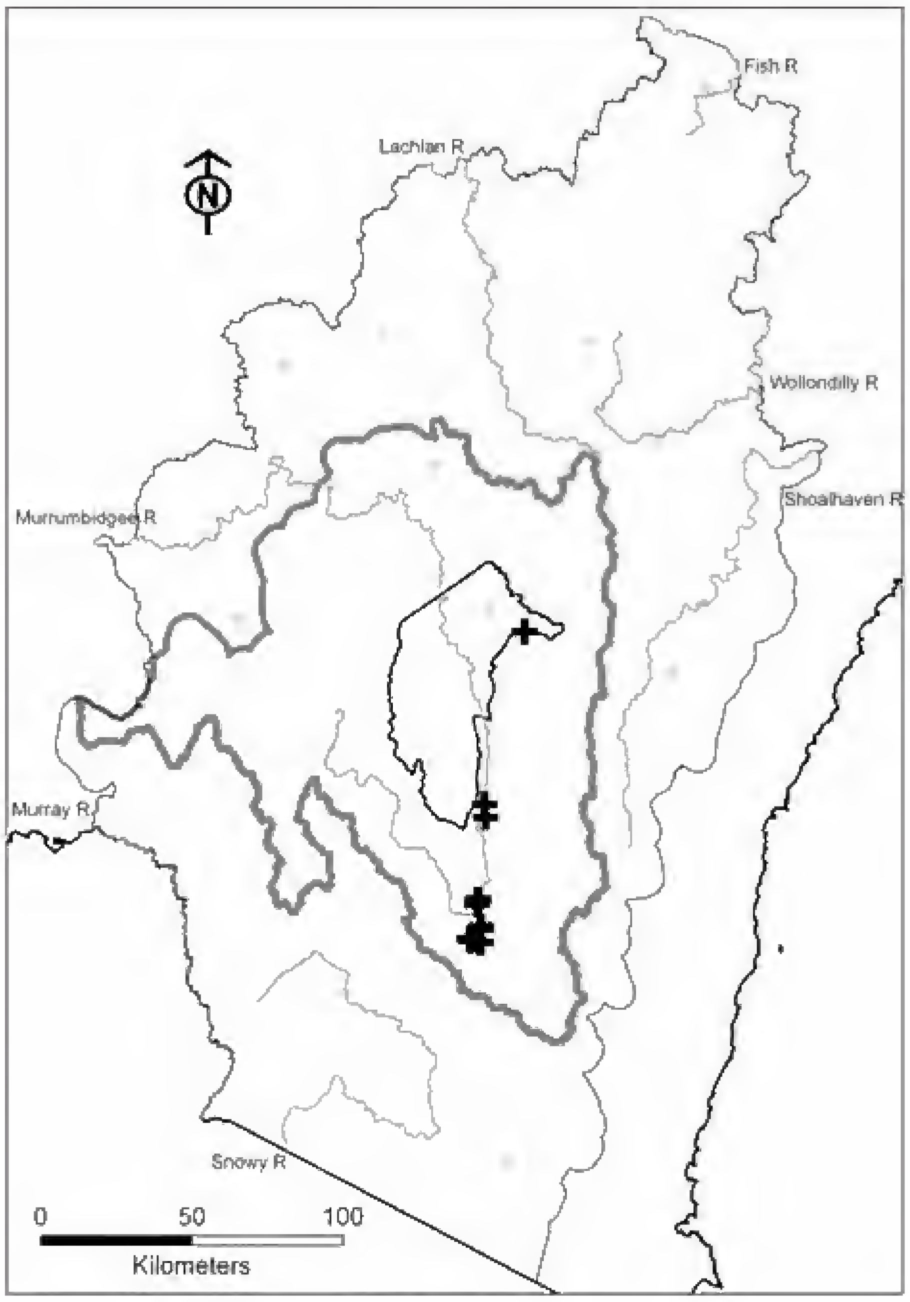

Fig. u191: Distribution of field samples assigned to this community.

Class: Upper Riverina Dry Sclerophyll Forests

u43: Mealy Bundy – *Acacia implexa – Allocasuarina verticillata – Ricinocarpos bowmanii* tall grassy open woodland on serpentinite in the Coolac-Goobarragandra area primarily of the upper South Western Slopes bioregion

Scientific Name: *Eucalyptus nortonii / Allocasuarina verticillata – Acacia implexa / Ricinocarpos bowmanii – Xanthorrhoea glauca* subsp. *angustifolia / Rytidosperma pilosum – Austrostipa scabra – Themeda australis*

Number of samples:	4
Richness [mean (±SD)]:	34 (2)
Slope (degrees):	(9) 14–15 (25)
Altitude (m asl):	(237) 505–644 (694)
Ave. Annual Rainfall (mm):	(687) 972–1083 (1148)
Temp. Annual Range (°C):	(26.7) 26.8–27.3 (28.5)

Vegetation Description: Community u43 is restricted to Cooolac serpentinite, and generally characterised by scattered or isolated *Eucalyptus nortonii* and *Acacia implexa* within a sparse to patchy tall shrub layer of *Allocasuarina verticillata*. Frequently, *Allocasuarina verticillata* can be the dominant woody species. Distinctive scattered *Xanthorrhoea glauca* subsp. *angustifolia* and low *Ricinocarpos bowmanii* are often present. The groundlayer commonly contains a high diversity of grass taxa including *Rytidosperma pilosum*, *Austrostipa scabra*, *Bothriochloa macra*, *Themeda australis*, *Poa sieberiana*, *Panicum effusum*, *Rytidosperma racemosum* and *Elymus scaber*. Plots and observations suggest that this vegetation is also characterised by the presence of *Ptilotus* species, plants typically found in drier environments west of the study area. Other common groundlayer plants include *Carex breviculmis*, *Lomandra filiformis*, *Daucus glochidiatus*, *Senecio quadridentatus*, *Scutellaria humilis*, *Tricoryne elatior*, *Dichondra repens*, *Cheilanthes sieberi*, *Pleurosorus rutifolius*, *Convolvulus angustissimus* and *Clematis microphylla*. Field observations suggest that tree and shrub cover are patchy on the Coolac serpentinite, where this community may occur as a woodland, shrubland or grassland. Patchiness in woody plant cover in this community may result from properties of the serpentinite landscape, past clearing events, or a combination of both.

This distinctive community is restricted to soils derived from the Coolac serpentinite formation, a narrow north-south belt of mixed intrusive/metamorphic ultramafic rocks running from east of Coolac/Pettits south along the Mooney Mooney and Honeysuckle Ranges through Gobarralong, Brungle Creek, Wyangle to Goobarragandra. These soils are relatively rich in magnesium and iron-group elements (cobalt, chromium, iron, manganese and nickel) and poor in calcium and potassium, conditions which inhibit the growth of some plant species (Lyons *et al.* 1974). Average annual rainfall along the Honeysuckle Range is moderately high but local conditions may be harsh and dry; soils along this steep-sided range are commonly shallow to skeletal with much exposed rock, and west-facing slopes are likely to experience high summer evaporation rates.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia decora	2	25	1	<1	P
Acacia implexa	2	100	1	2	P
Acacia penninervis	2	25	2	<1	P
Allocasuarina verticillata	3	75	1	<1	P
Austrostipa densiflora	1	25	1	1	P
Austrostipa rudis	1	25	2	<1	P
Austrostipa scabra	2	75	1	4	P
Bothriochloa macra	3	50	1	3	P
Carex breviculmis	2	75	1	13	P
Cheilanthes sieberi	2	75	1	9	P
Clematis microphylla	2	25	1	<1	P
Convolvulus angustissimus	2	75	1	3	P
Crassula sieberiana	1	50	1	6	P
Daucus glochidiatus	2	75	1	8	P
Dichanthium sericeum	1	25	1	<1	P
Eucalyptus nortonii	2	75	3	3	P
Goodenia spp.	2	25	1	<1	P
Hibbertia calycina	1	25	1	<1	P
Oxalis exilis	2	50	1	5	P
Panicum effusum	2	50	1	3	P
Pleurosorus rutifolius	1	25	1	<1	P
Ptilotus spp.	1	25	0	0	P
Ptilotus semilanatus	2	25	0	0	P
Ricinocarpos bowmanii	2	75	0	0	P
Rytidosperma monticola	2	25	2	1	P
Rytidosperma pilosum	2	75	2	9	P
Rytidosperma setaceum	2	25	1	<1	P
Schoenus apogon	1	50	1	5	P
Scutellaria humilis	2	50	1	2	P
Senecio bathurstianus	1	25	1	1	P
Senecio quadridentatus	2	100	1	6	P
Themeda australis	2	100	2	21	P
Thysanotus patersonii	1	25	1	1	P
Tricoryne elatior	2	50	1	4	P
Wahlenbergia gracilenta	1	50	1	<1	P
Wahlenbergia luteola	2	50	1	1	P
Xanthorrhoea glauca subsp. *angustifolia*	3	75	2	<1	P
Dichondra repens	2	50	2	21	C
Elymus scaber	2	50	1	21	C
Gonocarpus tetragynus	1	50	2	48	C
Hovea linearis	1	50	1	13	C
Hydrocotyle laxiflora	1	50	2	30	C
Lomandra filiformis subsp. *coriacea*	1	75	2	19	C
Lomandra filiformis subsp. *filiformis*	2	50	1	16	C
Oxalis perennans	2	50	1	13	C
Poa sieberiana	2	75	2	48	C
Rumex brownii	1	50	1	9	C
Rytidosperma racemosum	3	50	2	10	C

Threatened communities: Nil, but may be eligible for listing.

Equivalent vegetation types: Identified by Mulvaney *et al.* (2005) as Serpentine Woodland, and by Benson *et al.* (2010) as VCA 301 [*Drooping Sheoke – Ricinocarpus bowmannii – grasstree tall open shrubland of the Coolac – Tumut Serpentinite Belt*].

Frequently occurring weeds: Grazed areas of this community are widely invaded by common south-western slopes exotic pasture plants. The following exotic plant taxa were recorded in 30% or more of plots assigned to this type: *Acetosella vulgaris* (0.5), *Avena barbata* (0.5), *Briza maxima* (1.00), *Bromus diandrus* (0.75), *Bromus hordeaceus* (0.5), *Carthamus lanatus* (0.5), *Hypericum perforatum* (0.75), *Hypochaeris glabra* (0.5), *Petrorhagia nanteuilii* (1), *Rosa rubiginosa* (0.5), *Rostraria cristata* (0.5), *Sonchus oleraceus* (0.5), *Trifolium angustifolium* (0.75), *Trifolium arvense* (0.5), *Trifolium campestre* (0.5), *Trifolium dubium* (0.5), *Trifolium glomeratum* (0.5).

Plate u43: Community u43 with scattered *Allocasuarina verticillata*, *Eucalyptus nortonii* and *Acacia decora* growing on a serpentinite substrate. Honeysuckle Range, plot UMC418.

Plate u66: Community u66 dominated by *Eucalyptus nortonii* with a patchy shrub and ground layer. Isaacs Ridge NR, ACT.

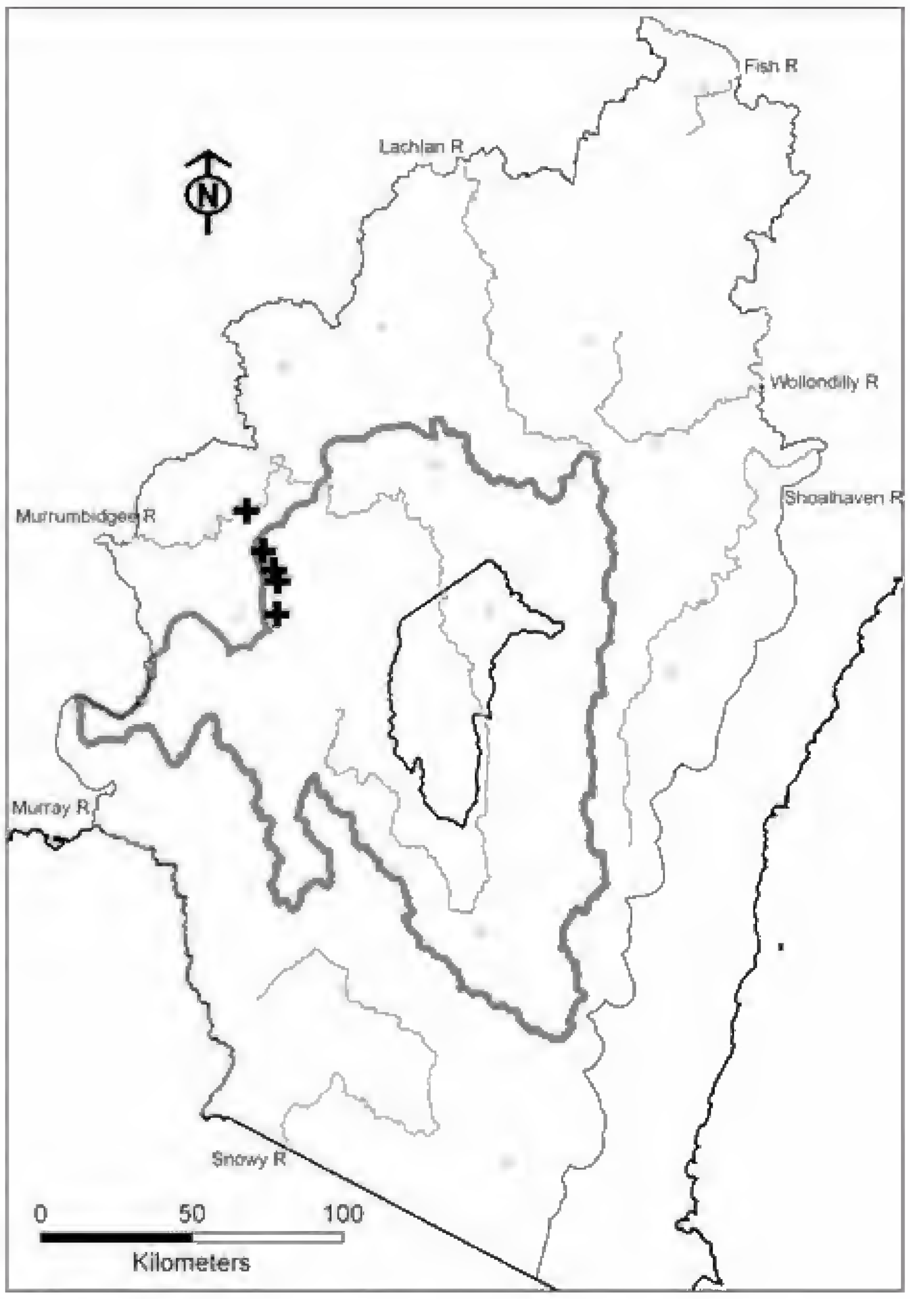

Fig. u43: Distribution of field samples assigned to this community.

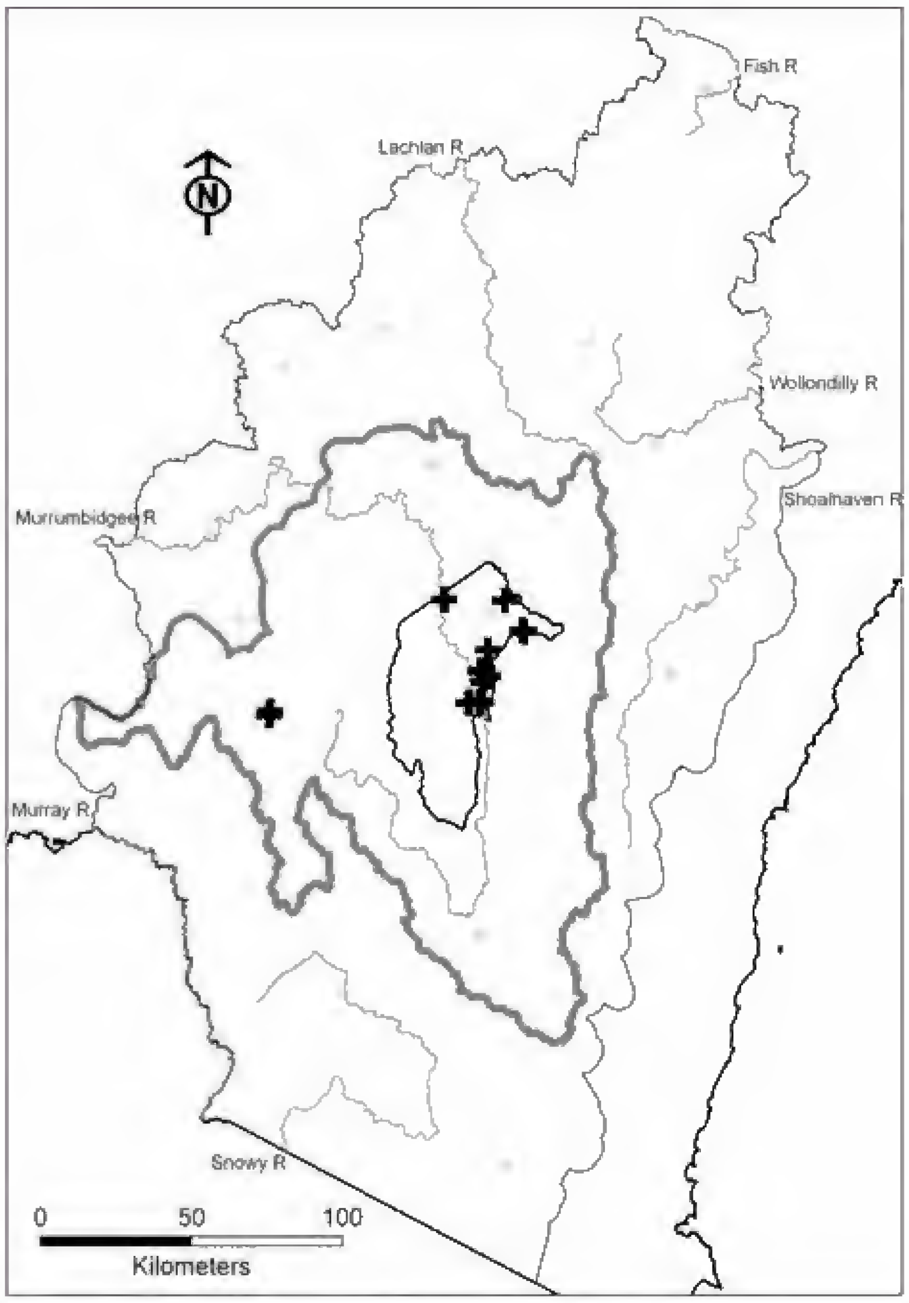

Fig. u66: Distribution of field samples assigned to this community.

Threats: Community u43 is grazed by stock across most of its extent, and some areas have been subject to clearing of tree or shrub layers. Mineral prospecting and mining may have local impacts; past mining took place at Tumut Gold Mine and McAlpine Mine, and significant areas of serpentinite are covered by current mineral exploration licences.

Reservation status: Not represented in any conservation reserves. Small areas exist in two TSRs, at the north and south ends of its range; a larger area is within Red Hill SF (which may be subject to a grazing lease); the remainder is private freehold.

Extent of clearing: Uncertain. Further investigation is required into the causes of the sparse tree and shrub cover observed across this landscape; whether it is partially due to the influence of serpentinite on plant growth, or is an artefact of historic clearing for pasture development. Some areas may have been cleared, but it is also possible that some areas are naturally open.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Lyons, M.T., Brooks, R.R. & Craig, D.C. (1974) The influence of soil composition on the vegetation of the Coolac serpentinite belt in New South Wales. *Journal and Proceedings of the Royal Society of New South Wales* 107: 67–75; Mulvaney, M., Boak, M., Priday, S., Hudson, K. & Crane, M. (2005) The native vegetation of Gundagai shire. NSW Department of Environment and Conservation, Queanbeyan.

u66: Mealy Bundy – Red Stringybark grass-forb mid-high open forest of the South Eastern Highlands and Upper Slopes Subregion of the South Western Slopes bioregion

Scientific Name: *Eucalyptus nortonii* ± *Eucalyptus macrorhyncha – Eucalyptus polyanthemos / Cassinia longifolia – Hibbertia obtusifolia / Poa sieberiana – Daucus glochidiatus – Cheilanthes austrotenuifolia*

Number of samples: 16
Richness [mean (±SD)]: 41 (10)
Slope (degrees): (8) 12–19 (28)
Altitude (m asl): (443) 613–740 (812)
Ave. Annual Rainfall (mm): (611) 672–724 (1076)
Temp. Annual Range (°C): (25.8) 26.3–27.1 (27.5)

Vegetation Description: Community u66 is a mid-high open woodland to open forest characterised by *Eucalyptus nortonii* often with *Eucalyptus macrorhyncha* or *Eucalyptus polyanthemos*, and occasionally with *Brachychiton populneus* or *Callitris endlicheri*. *Allocasuarina verticillata* and *Acacia implexa* may be present in low abundance in the midstorey, along with shrubs including *Cassinia longifolia*, *Bursaria spinosa*, *Pimelea curviflora* and *Hibbertia obtusifolia*. The groundlayer is generally patchy with grasses including *Poa sieberiana*, *Rytidosperma* spp. and *Austrostipa scabra* and forbs including *Hydrocotyle laxiflora*, *Daucus glochidiatus*, *Acaena ovina*, *Geranium solanderi*, *Gonocarpus tetragynus*, *Lomandra filiformis* subsp. *filiformis* and *Wahlenbergia stricta*. The fern *Cheilanthes austrotenuifolia* and sedge *Carex appressa* may be present.

Community u66 is located mainly on low hills of sandstone and acid–volcanic (ignimbrite, rhyolite, tuff) substrates within the northern ACT and surrounds, with further occurrences sampled from steep slopes around Talbingo to the west. It is likely that this community requires greater floristic sampling to refine its description. Around Canberra, it generally occurs on slightly less fertile soils than Community u29 [*Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of the South Eastern Highlands bioregion*] and Community u178 [*Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands*]. Around Talbingo it grades into Community u148 [*Red Stringybark – Red Box grass-forb tall open forest of the upper South Western Slopes and western South Eastern Highlands bioregions*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia implexa	1	31	1	2	P
Acaena ovina	1	69	1	8	P
Ajuga australis	1	31	1	8	P
Allocasuarina verticillata	1	38	1	<1	P
Austrostipa scabra	1	56	2	4	P
Bothriochloa macra	1	31	1	3	P
Brachychiton populneus	1	31	1	2	P
Bursaria spinosa	1	63	1	10	P
Callitris endlicheri	1	31	2	1	P
Carex inversa	1	63	1	8	P
Cassinia longifolia	1	75	1	16	P
Cheilanthes austrotenuifolia	1	69	1	3	P
Cheilanthes sieberi	1	50	1	9	P
Clematis leptophylla	1	50	1	1	P
Crassula sieberiana	1	56	1	5	P
Cymbonotus lawsonianus	1	38	1	5	P
Cynoglossum suaveolens	1	44	1	3	P
Daucus glochidiatus	1	75	1	8	P
Desmodium varians	1	56	1	12	P
Dodonaea viscosa	1	25	1	2	P
Eucalyptus nortonii	3	63	3	3	P
Eucalyptus polyanthemos	3	31	3	3	P
Euchiton sphaericus	1	50	1	7	P
Galium gaudichaudii	1	50	1	10	P
Geranium solanderi	1	69	1	19	P
Hibbertia obtusifolia	1	75	1	34	P
Hydrocotyle laxiflora	1	100	2	29	P
Kunzea ericoides	1	38	2	4	P
Lepidosperma laterale	1	63	1	9	P
Lomandra filiformis subsp. *filiformis*	1	69	1	16	P
Luzula densiflora	1	38	1	6	P
Oxalis perennans	1	56	1	13	P
Pimelea curviflora	1	50	1	6	P
Plantago varia	1	44	1	11	P
Poa sieberiana	1	94	2	48	P
Pterostylis nana	1	31	1	<1	P
Pultenaea procumbens	1	31	1	4	P
Rumex brownii	1	38	1	9	P
Rytidosperma spp.	1	63	1	7	P
Scutellaria humilis	1	31	1	1	P
Senecio quadridentatus	1	50	1	5	P
Vittadinia cuneata	1	31	1	2	P
Wahlenbergia spp.	1	25	1	5	P
Wahlenbergia stricta	1	69	1	18	P
Wurmbea dioica	1	38	1	3	P
Glycine clandestina	1	56	1	29	C
Gonocarpus tetragynus	1	69	2	48	C
Hypericum gramineum	1	56	1	25	C
Senecio prenanthoides	1	50	1	19	C

Threatened communities: Nil.

Equivalent vegetation types: No obvious equivalent communities. There are a number of similar VCA plant communities including VCA 294, 297, 306, 310, 311 and 316 (Benson *et al.* 2010).

Frequently occurring weeds: This community is widely distributed across freehold (leasehold in the ACT) grazing land, and has experienced substantial disturbance and subsequent weed invasion. Weed species typical of the grazing environments of the Southern Tablelands and South Western Slopes are prevalent within this community, most notably

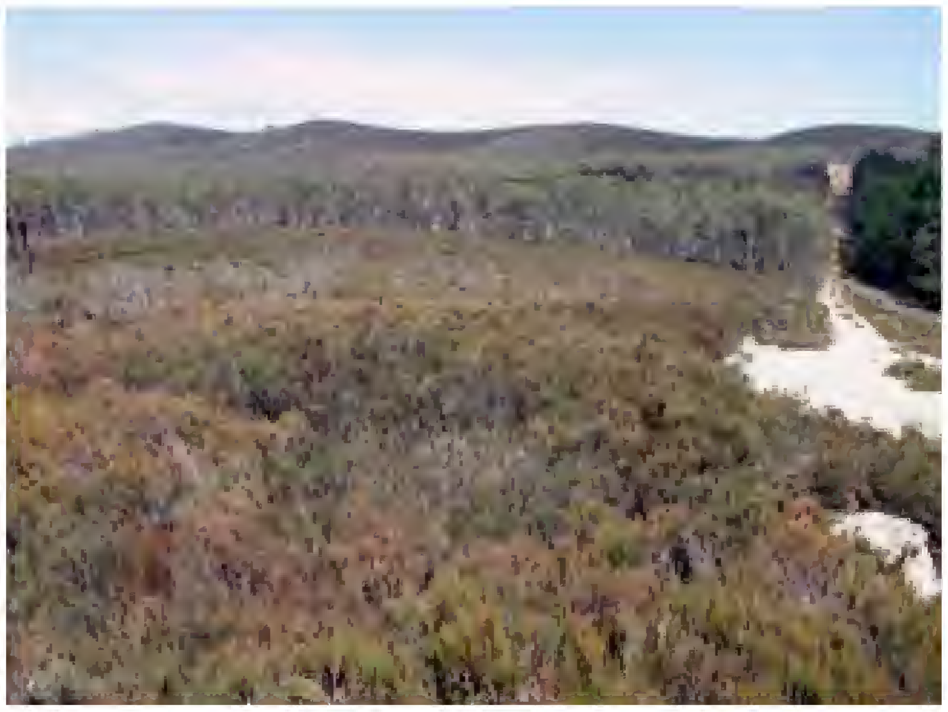

Plate e53: Community e53 in foreground, characterised by dense thickets of *Allocasuarina nana*. Coolumbooka NR.

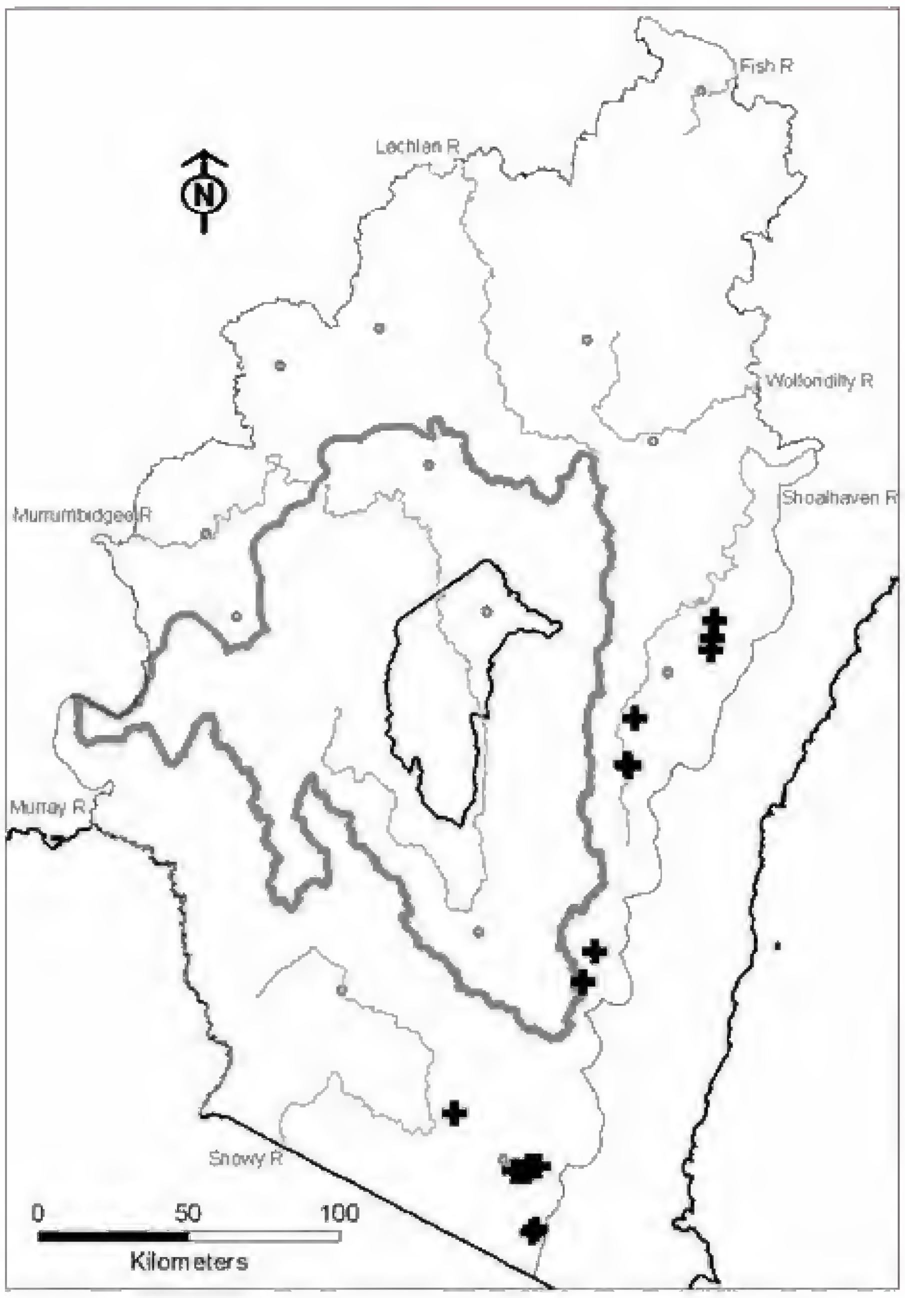

Fig. e53: Distribution of field samples assigned to this community.

Aira elegantissima (0.38), *Briza minor* (0.31), *Bromus diandrus* (0.38), *Hypericum perforatum* (0.38), *Hypochaeris radicata* (0.75), *Lysimachia arvensis* (0.31), *Orobanche minor* (0.31), *Petrorhagia nanteuilii* (0.5), *Rosa rubiginosa* (0.44), *Sonchus oleraceus* (0.31), *Trifolium arvense* (0.88), *Trifolium campestre* (0.5), *Trifolium glomeratum* (0.31) and *Vulpia myuros* (0.44).

Threats: Grazing continues to degrade this community, reducing native species diversity and encouraging weed invasion. It is also likely that minor to moderate clearing still occurs, along with the removal of fallen timber for firewood.

Reservation status: Examples of this community are found in Kosciuszko NP and Namadgi NP as well as Isaac Ridge, Mt. Majura, Rob Roy Reserve and Tuggeranong Hill Reserve (parts of Canberra Nature Park).

Extent of clearing: Likely to be moderately cleared where it occurs on lower slopes or in close proximity to fertile farming country.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney.

Formation: Heathlands

Class: Southern Montane Heaths

e53: *Allocasuarina nana* shrubland on exposed skeletal ridges primarily in the eastern South Eastern Highlands bioregion

Scientific Name: *Allocasuarina nana – Brachyloma daphnoides / Lomandra glauca – Gonocarpus tetragynus – Stylidium graminifolium sens. lat.*

Number of samples:	22
Richness [mean (±SD)]:	19 (9)
Slope (degrees):	(0) 6–16 (21)
Altitude (m asl):	(506) 678–857 (1081)
Ave. Annual Rainfall (mm):	(584) 881–957 (1018)
Temp. Annual Range (°C):	(23.1) 23.6–24.2 (25.6)

Vegetation Description: Community e53 is a dense shrubland to 1.5 metres tall (but often less that 0.5 metres) dominated by *Allocasuarina nana* and *Brachyloma daphnoides,* with *Hakea dactyloides* frequently occurring as an emergent to 3 metres tall. *Epacris impressa*, *Dampiera* spp. and prostrate shrubs including *Isopogon prostratus* and *Mirbelia platylobioides* are also common. Where breaks in the dense shrub layer occur, patches of grasses and sedges are common, including *Rytidosperma pallidum*, *Lomandra glauca* and *Lepidosperma tortuosum*, along with forbs including *Stylidium graminifolium sens. lat.*, *Gonocarpus tetragynus* and *Patersonia sericea* var. *longifolia*. The Endangered (TSC Act 1995) *Westringia kydrensis* and *Dampiera fusca* are known to occur in this community, as are the rare *Euryomyrtus denticulata* and *Haloragodendron monospermum*. Species diversity appears to increase further north of the upper Murrumbidgee catchment. Occasionally, sparse to isolated emergent *Eucalyptus dives* or other eucalypts from adjacent forest communities may be present.

Community e53 is defined by data from sites extending from Coolumbooka NR (east of Bombala) to north of Mongarlowe. Within the upper Murrumbidgee catchment, it is known to occur on exposed slopes and ridges in Dangelong NR south of Numeralla, and may occur further north within the catchment in similar situations on the western fall of the Great Divide. It occurs on skeletal sandy loams derived from metasediments, acid volcanics or granitoids, and is likely to occur in exposed areas associated with Community p9 [*Brittle Gum – Scribbly Gum shrubby tall dry open forest*] and Community e24 [*Mountain Gum – Snow Gum subalpine very tall dry shrubby open forest primarily in the Kybeyan – Gourock subregion of the South Eastern Highlands bioregion*], and possibly other communities on ridge country in the east of the upper Murrumbidgee catchment.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Allocasuarina nana	5	100	2	<1	P
Austrostipa pubinodis	2	29	2	<1	P
Brachyloma daphnoides	2	81	1	16	P
Cassytha glabella	1	29	1	<1	P
Dampiera spp.	2	38	1	<1	P
Entolasia stricta	2	29	2	4	P
Epacris impressa	2	33	2	3	P
Gompholobium huegelii	2	24	1	5	P
Gompholobium minus	1	24	1	1	P
Hakea dactyloides	2	48	2	3	P
Isopogon prostratus	2	33	2	<1	P
Lepidosperma gunnii	2	29	1	5	P
Lepidosperma tortuosum	1	38	1	<1	P
Lomandra glauca	2	52	2	4	P
Mirbelia platylobioides	2	33	1	<1	P
Patersonia sericea var. *longifolia*	2	33	2	1	P
Platysace lanceolata	2	29	2	5	P
Rytidosperma pallidum	2	48	2	17	P
Rytidosperma tenuius	1	24	2	1	P
Stylidium graminifolium sens. lat.	1	62	1	25	P
Gonocarpus tetragynus	1	62	2	48	C

Threatened communities: Nil.

Equivalent vegetation types: This community is equivalent to HLe53 [*Southern Montane Heath*] described by Tozer *et al.* (2010), and overlaps with the communities VG134 [*Eastern Tablelands Dry Heath*] and VG135 [*Southern Escarpment (Wadbilliga) Moist Heath*] identified by Gellie (2005), with the latter type defined by additional dominant species including *Kunzea* sp. 'Wadbilliga' and *Banksia canei*.

Frequently occurring weeds: No exotic taxa have been recorded from this community, probably due to its occurrence on exposed and infertile substrates.

Threats: Because this community occurs on soils of low fertility and in exposed situations, clearing has been minimal. Grazing threats are likely to be minimal due to a dominance of relatively unpalatable species and difficulty of stock penetrating its dense shrubby layer. Infrequent fire may be changing the structure and composition of this community, with observations suggesting an optimum burn frequency of once every 10 – 25 years (J. Miles, pers. comm.). Too frequent fire may affect the occurrence of obligate seeders.

Reservation status: While the distribution within the upper Murrumbidee catchment is unknown, all known examples are conserved in Dangelong NR. To the east of the upper Murrumbidgee catchment, more than 50% of the esimated pre-clearing extent of Community e53 (as defined by Tozer *et al.* 2010) is considered to be reserved.

Extent of clearing: Due to its occurrence in exposed locations and on soils of low fertility, this community is considered to be largely intact (Tozer *et al.* 2010).

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Formation: Forested Wetlands

Class: Eastern Riverine Forests

p32d: River She-oak riparian forest on sand/gravel alluvial soils along major watercourses of the South Eastern Highlands and upper South Western Slopes bioregions

Scientific Name: *Casuarina cunninghamiana / Acacia dealbata / Microlaena stipoides – Dichondra repens – Lomandra longifolia – Echinopogon ovatus – Poa labillardierei*

Number of samples:	15
Richness [mean (±SD)]:	28 (8)
Slope (degrees):	(0) 5–26 (36)
Altitude (m asl):	(259) 507–622 (702)
Ave. Annual Rainfall (mm):	(688) 697–728 (909)
Temp. Annual Range (°C):	(25.5) 26.3–27.6 (28.6)

Vegetation Description: Community p32d is characterised by a tall tree canopy of *Casuarina cunninghamiana*. The shrub layer is often sparse and may include scattered *Acacia dealbata*, *Bursaria spinosa* or *Kunzea ericoides*, and patches of young *Casuarina cunninghamiana* plants. Groundlayer is often dominated by bare soil/rock and thick litter of *Casuarina cunninghamiana* branchlets, and a dense tree canopy often contributes to a shady moist ground environment. Groundlayer plants may be sparse or patchy, and frequent species include *Dichondra repens*, *Echinopogon ovatus*, *Geranium solanderi*, *Microlaena stipoides*, *Poa labillardierei*, *Rumex brownii*, *Hydrocotyle laxiflora*, *Lomandra longifolia* and a variety of small ferns and sedges.

This community occurs across the study area on major rivers and streams including the Murrumbidgee, Abercrombie, Tarlo and Wollondilly Rivers. Plots assigned to Community p32d by the current study were recorded from the Retreat and Abercrombie Rivers in the north of the study area to lower altitudes on rivers in the ACT, on the Murrumbidgee River below Burrinjuck Dam and along the Goodradigbee River. This community occurs on river gravel, cobbles and coarse sandy alluvium along permanent and semi–permanent watercourses in relatively narrow confined channels subject to high-velocity flows. On meandering tableland watercourses with deeper, finer-grained alluvial silts and loams, it is replaced by Community u173 [*River Red Gum ± Apple Box very tall grass-forb riparian woodland on alluvial flats in the South Eastern Highlands and upper South Western Slopes bioregions*]. To the west of the study area where major rivers cut through deep fine-grained silts and loams and sand lenses on broad river flats, it is replaced on riverbanks by a mixed River Red Gum – River She-oak community (e.g. see Mulvaney *et al.* 2005), which occurs in the study area on broad sandy flats on the Murrumbidgee at Jugiong and Gobarralong in the South Western Slopes. A similar but distinct River She-oak dominated community with increasing elements of moist eucalypt forest and rainforest in the midstorey and groundlayer (FoWp32 described by Tozer *et al.* 2010) occurs to the east of the study area in coastal escarpment streams.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Adiantum aethiopicum	1	38	2	3	P
Asplenium flabellifolium	1	44	1	9	P
Bursaria spinosa	1	50	1	10	P
Carex spp.	2	25	1	2	P
Casuarina cunninghamiana	4	100	4	<1	P
Cheilanthes sieberi	1	38	1	9	P
Dichondra repens	2	81	2	20	P
Echinopogon ovatus	1	63	1	10	P
Eucalyptus bridgesiana	1	31	3	7	P
Geranium solanderi	1	56	1	19	P
Kunzea ericoides	3	38	2	4	P
Microlaena stipoides	2	94	2	34	P
Pellaea falcata	1	25	2	2	P
Plantago debilis	2	25	2	4	P
Poa labillardierei	1	50	2	10	P
Rumex brownii	1	63	1	9	P
Rytidosperma racemosum	2	38	2	10	P
Senecio quadridentatus	2	38	1	5	P
Urtica incisa	1	38	1	2	P
Acacia dealbata	2	56	2	26	C
Acaena novae-zelandiae	2	50	1	28	C
Hydrocotyle laxiflora	2	56	2	30	C
Lomandra longifolia	2	75	2	42	C
Stellaria pungens	2	50	2	31	C

Threatened communities: Nil.

Equivalent vegetation types: This community is closely related to FoWp32 [*Riverbank Forest*] described by Tozer *et al.* (2010) for the coast and tablelands. The inclusion of additional tableland and slopes field samples in the current study area indicates that a split is warranted between the moist *Casuarina cunninghamiana* forests of the coast and coastal escarpments with their rainforest and wet sclerophyll elements, and the drier *Casuarina cunninghamia* forests of the tablelands and slopes containing elements of adjacent dry forests and woodlands. Community p32d also represents a dry subset of VG53 [*Riparian Acacia Shrub/Grass/Herb Forest*] described by Gellie (2005), and is described by Benson *et al.* (2010) as VCA 85 [*River Oak forest and woodland wetland of the NSW South-western Slopes and South Eastern Highlands bioregions*].

Frequently occurring weeds: This community is susceptible to invasion by a wide variety of exotic plant species. The following taxa were recorded from 30% or more of plots assigned to this community: *Acetosella vulgaris* (0.57), *Cirsium vulgare* (0.36), *Conyza bonariensis* (0.43), *Euphorbia peplus* (0.36), *Holcus lanatus* (0.36), *Hypochaeris radicata* (0.71), *Lysimachia arvensis* (0.43), *Modiola caroliniana* (0.43), *Plantago lanceolata* (0.36), *Prunella vulgaris* (0.43), *Rosa rubiginosa* (0.43), *Rubus fruticosus* sp. agg. (0.5), *Sonchus oleraceus* (0.79).

Threats: Generally not cleared, as it tends to be restricted to a narrow band of relatively infertile sand/gravel/cobble alluvium subject to frequent flooding. In some tableland rural environments a narrow strip of this community may be the only extant woody vegetation. However, many examples of this community across all tenures are degraded by weed invasion, and examples on private land are commonly subject to frequent stock grazing.

Reservation status: Plots were recorded from Abercrombie River NP, Brindabella SCA, Burrinjuck NR, Razorback NR and Tarlo River NP in NSW, and Woodstock NR, Stony Creek NR, Bullen Range NR and Kambah Pool Recreation Area in the ACT. Likely to occur in many other conservation reserves along permanent watercourses in dissected country.

Extent of clearing: Generally minor.

Plate p32d: Community p32d on the Murrumbidgee River beside Nanangroe Road (plot UMC404), dominated by *Casuarina cunninghamiana* with woody debris from December 2010 floods.

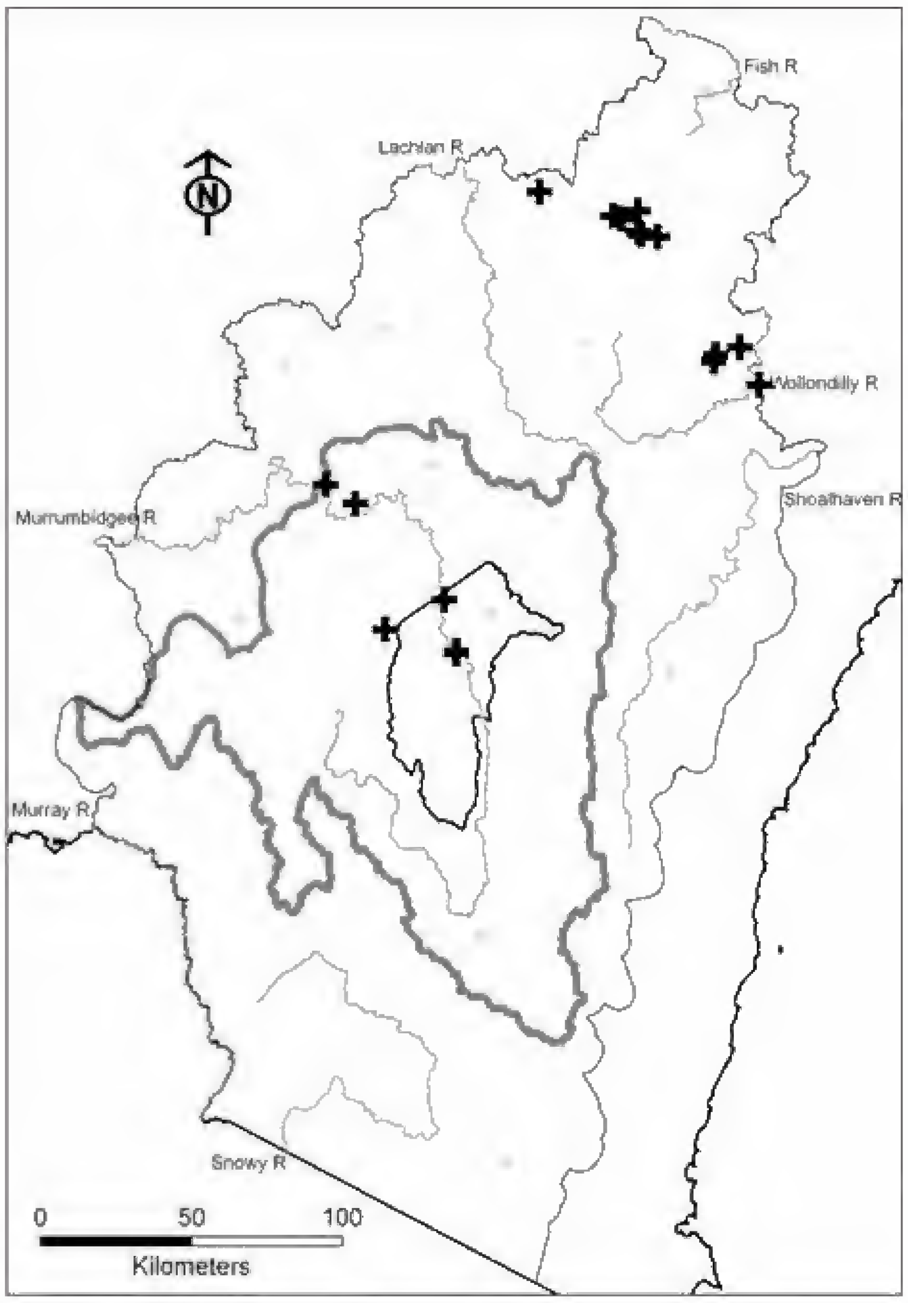

Fig. p32d: Distribution of field samples assigned to this community.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

p56: *Leptospermum grandifolium – Hakea microcarpa – Lomatia myricoides* very tall riparian shrubland of the eastern South Eastern Highlands bioregion

Scientific Name: *Leptospermum grandifolium – Hakea microcarpa – Lomatia myricoides – Leptospermum obovatum / Carex gaudichaudiana – Poa labillardierei – Scirpus polystachyus*

Number of samples:	9
Richness [mean (±SD)]:	24 (5)
Slope (degrees):	(1) 3–6 (21)
Altitude (m asl):	(505) 721–916 (993)
Ave. Annual Rainfall (mm):	(605) 710–916 (1032)
Temp. Annual Range (°C):	(23.2) 24.2–25.9 (26.5)

Vegetation Description: Community p56 is a distinctive riparian shrubland that occurs in a narrow band along beds and lower terraces of rivers and major streams of the eastern southern tablelands where substrates are dominated by exposed bedrock with shallow to skeletal pockets of coarse sand, gravel or cobble alluvium. A tree layer is often absent, or exists as scattered small individuals of from adjacent plant communities including *Eucalyptus viminalis* and *Eucalyptus pauciflora* subsp. *pauciflora*. A characteristic dense to patchy layer of low to tall shrubs is commonly dominated by *Hakea microcarpa*, *Leptospermum grandifolium*, *Leptospermum obovatum*, *Lomatia myricoides* and other riparian taxa. Groundlayer ranges from dense to patchy depending on flood disturbance and levels of bare rock and open water cover; areas of exposed sandy soil are commonly bound by tussocks of *Poa labillardierei*, *Lomandra longifolia* and *Carex appressa* and soft herbs including *Epilobium* spp., *Hydrocotyle sibthorpioides* and *Acaena novae-zelandiae*, while flow-lines, pools and wet banks contain a mix of aquatic and semi-aquatic plants commonly including *Carex gaudichaudiana*, *Juncus*, *Ranunculus* and *Myriophyllum* spp. and tall clumps of *Scirpus polystachyus*.

This community is recorded from eastern tableland streams subject to frequent high-velocity flows, including the upper Shoalhaven and upper Tuross Rivers, Bredbo River, Big Badja River, Maclaughlin River, Bombala River, Dragon Swamp Creek and White Rock River, and is likely to occur on other streams across this range with suitable rocky alluvial habitat. Where deeper sandy alluvial deposits develop, this community is replaced by Community p520 [*Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion*]. Further to the west on similar shallow sand/gravel/cobble alluvium it is replaced by Community u181 [*Callistemon sieberi – Kunzea ericoides rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes bioregions].*

Plate p56: Community p56 with *Leptospermum obovatum* and a diverse array of grasses, sedges, rushes and forbs fringing the Bredbo River south of Jerangle, Frogs Hollow TSR (plot UMC425).

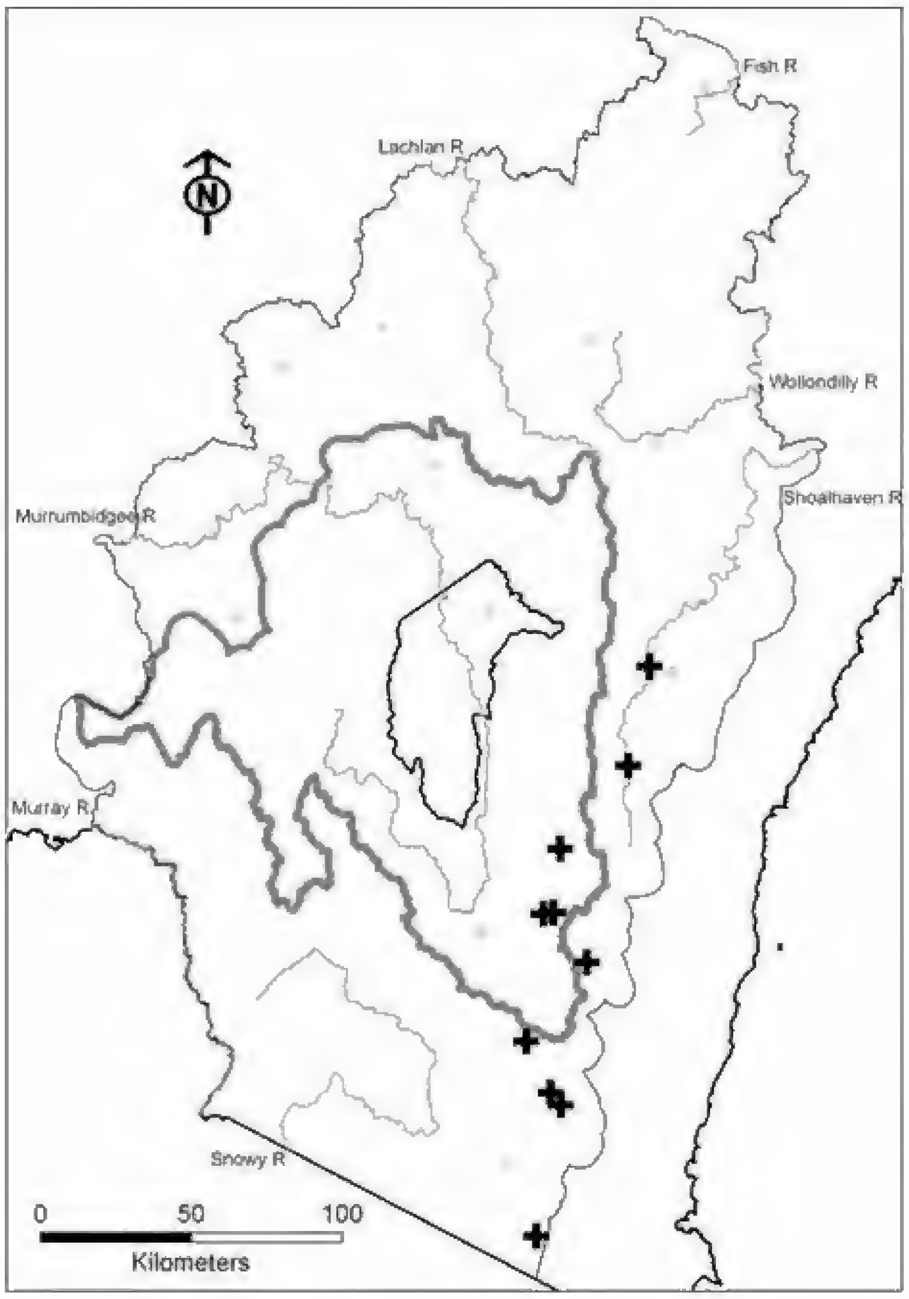

Fig. p56: Distribution of field samples assigned to this community.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia siculiformis	2	22	1	<1	P
Blechnum minus	2	22	1	1	P
Callistemon subulatus	2	33	1	<1	P
Carex appressa	2	44	1	7	P
Carex gaudichaudiana	3	89	2	4	P
Elatine gratioloides	1	33	1	<1	P
Epilobium spp.	2	67	1	1	P
Eucalyptus viminalis	1	67	3	13	P
Grevillea lanigera	2	44	1	3	P
Hakea microcarpa	2	78	1	3	P
Hydrocotyle sibthorpioides	2	44	2	4	P
Hypericum japonicum	2	44	1	4	P
Juncus falcatus	2	22	1	<1	P
Juncus gregiflorus	2	22	1	<1	P
Leptospermum grandifolium	3	67	3	2	P
Leptospermum lanigerum	5	22	2	<1	P
Leptospermum obovatum	3	56	1	<1	P
Lomatia myricoides	2	56	1	12	P
Micrantheum hexandrum	1	22	1	<1	P
Myriophyllum spp.	2	33	2	<1	P
Ozothamnus ferrugineus	1	22	2	<1	P
Persicaria prostrata	1	22	2	1	P
Poa labillardierei	2	89	2	10	P
Pultenaea altissima	1	33	1	<1	P
Ranunculus amphitrichus	1	44	2	<1	P
Schoenoplectus validus	2	22	1	<1	P
Scirpus polystachyus	2	67	1	<1	P
Typha orientalis	1	22	0	0	P
Acaena novae-zelandiae	2	44	1	28	C
Elymus scaber	1	44	1	21	C
Lomandra longifolia	2	56	2	42	C

Threatened communities: Nil.

Equivalent vegetation types: This community is equivalent to FrWp56 [*Shoalhaven Riparian Scrub*] identified by Tozer *et al.* (2010), with the addition of a new plot from the Bredbo River.

Frequently occurring weeds: This riparian community is relatively moist and is subject to frequent disturbance by flooding, so is prone to invasion by a variety of exotic plant species. The following taxa were recorded from 30% or more of plots assigned to this community: *Acetosella vulgaris* (0.33), *Anthoxanthum odoratum* (0.33), *Holcus lanatus* (0.67), *Hypochaeris radicata* (0.44), *Plantago lanceolata* (0.33), *Prunella vulgaris* (0.56).

Threats: Weed invasion is likely to be the main ongoing threat to this community, particularly invasive perennial weeds such as *Rubus fruticosus* spp. agg. and *Hypericum perforatum* with the ability to survive major floods and gradually dominate the riparian zone and displace native plants.

Reservation status: Recorded from Deua NP and South East Forest NP, also likely to occur in many other conservation reserves along the eastern tableland ranges.

Extent of clearing: Likely to be very minor due to its rocky, flood-prone habitat.

References: Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

u181: *Callistemon sieberi – Kunzea ericoides* rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes bioregions

Scientific Name: *Callistemon sieberi – Kunzea ericoides – Acacia rubida – Bursaria spinosa / Rumex brownii – Lythrum hyssopifolia – Lomandra longifolia*

Number of samples:	10
Richness [mean (±SD)]:	25 (6)
Slope (degrees):	(0) 4–19 (25)
Altitude (m asl):	(360) 462–607 (749)
Ave. Annual Rainfall (mm):	(605) 648–675 (962)
Temp. Annual Range (°C):	(26.7) 27–27.4 (28)

Vegetation Description: Community u181 is characteristically a tall to low riparian shrubland, with a patchy to dense layer of shrubs commonly dominated by *Callistemon sieberi* and *Kunzea ericoides* with scattered *Acacia rubida* and *Bursaria spinosa*. Scattered emergent or flood-stunted trees sometimes occur. Ground cover tends to be dominated by exposed rock and bare sand/gravel alluvium, with scattered or patchy low moisture-loving plants including sedge and rush tussocks of *Lomandra longifolia*, *Juncus* spp. and *Carex appressa*, with forbs including *Lythrum hyssopifolia*, *Rumex brownii*, *Persicaria* spp. and *Epilobium* spp. and grasses such as *Rytidosperma racemosum*, *Microlaena stipoides* and *Elymus scaber*. *Eucalyptus camaldulensis* may be found as part of or adjacent to this community, where it is at the eastern edge of its range.

This community has been recorded from the Murrumbidgee River (around Michelago, Gigerline and Greenway), the Molonglo gorge and a Queanbeyan River tributary, in Yass River gorge and tributaries (Bogolong Creek), and on the Goobarragandra River east of Tumut. It was also observed on Lerida Creek near Gunning, and may occur elsewhere across western parts of the study area in suitable rocky riparian habitats. This community appears to be restricted to riparian areas of exposed rocky substrate with skeletal or shallow pockets of gravelly soil along western tableland streams, often in confined gorges through hilly country but also on small bedrock reefs exposed in streams through undulating tableland/slopes country.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dawsonii	1	20	1	<1	P
Acacia rubida	2	70	1	6	P
Alternanthera denticulata	1	20	1	<1	P
Bursaria spinosa	1	60	1	10	P
Callistemon sieberi	2	100	2	<1	P
Callitris endlicheri	2	40	3	1	P
Calytrix tetragona	2	30	2	1	P
Carex appressa	1	50	1	7	P
Cassinia spp.	1	20	1	1	P
Cheilanthes sieberi	1	50	1	9	P
Dodonaea viscosa subsp. *angustissima*	1	50	1	<1	P
Epilobium spp.	1	20	1	1	P
Eucalyptus camaldulensis	3	20	4	<1	P
Juncus spp.	1	30	1	2	P
Juncus usitatus	1	20	1	<1	P
Kunzea ericoides	2	90	2	4	P
Leptospermum obovatum	1	20	3	<1	P
Lespedeza juncea subsp. *sericea*	2	30	1	<1	P
Lythrum hyssopifolia	1	60	1	<1	P
Paspalum distichum	2	20	2	<1	P
Persicaria hydropiper	2	20	1	<1	P

Persicaria prostrata	2	20	2	1	P
Pomaderris angustifolia	1	20	1	<1	P
Rumex brownii	1	70	1	9	P
Rytidosperma racemosum	2	50	2	10	P
Acacia dealbata	1	40	2	26	C
Elymus scaber	2	50	1	21	C
Geranium solanderi	1	50	1	19	C
Lomandra longifolia	2	60	2	42	C
Microlaena stipoides	2	50	2	34	C
Poa labillardierei	2	40	2	10	C
Themeda australis	1	50	2	21	C

Threatened communities: Nil.

Equivalent vegetation types: This community has no equivalent Forest Ecosystem (Gellie 2005), however some plots were originally part of VG82 [*Montane Acacia Fern/Herb Forest*]. It appears to have affinities with VCA 333 [*Bottlebrush riparian shrubland wetland of the northern NSW South-western Slopes and southern Brigalow Belt South bioregions*] (Benson *et al.* 2010).

Frequently occurring weeds: Community u181 occurs along stream channels where moist conditions and frequent flooding and grazing disturbance allow the arrival, survival and reproduction of a wide variety of exotic plants. The following exotic species were recorded from 30% or more of the plots assigned to this type: *Acetosella vulgaris* (0.60), *Avena fatua* (0.30), *Briza maxima* (0.30), *Briza minor* (0.50), *Bromus diandrus* (0.50), *Bromus hordeaceus* (0.30), *Conyza bonariensis* (0.40), *Crataegus monogyna* (0.30), *Cynara cardunculus* (0.40), *Cynosurus echinatus* (0.40), *Cyperus eragrostis* (0.40), *Dactylis glomerata* (0.30), *Hypericum perforatum* (0.80), *Hypochaeris glabra* (0.40), *Hypochaeris radicata* (0.50), *Juncus bufonius* (0.30), *Lysimachia arvensis* (0.70), *Paspalum dilatatum* (0.30), *Petrorhagia nanteuilii* (0.60), *Plantago lanceolata* (0.90), *Polycarpon tetraphyllum* (0.40), *Rosa rubiginosa* (0.60), *Rubus fruticosus* spp. agg. (0.70), *Rumex crispus* (0.40), *Sanguisorba minor* (0.30), *Sonchus asper* (0.30), *Sonchus oleraceus* (0.30), *Trifolium angustifolium* (0.40), *Trifolium arvense* (0.70), *Trifolium campestre* (0.50), *Vulpia myuros f. megalura* (0.70).

Threats: Unlikely to have been widely cleared. Examples on freehold land are likely to be grazed except where streambanks have been protected by fencing. The habitat of this community is moist and subject to occasional flooding disturbance and it is highly prone to invasion by riparian weeds and exotic plants of adjacent pasture lands.

Reservation status: Plots of this community sampled in the ACT were located in Bullen Range NR, Molonglo Gorge NR and Gigerline NR. None of the plots from NSW assigned to this type were located in a conservation reserve; however plot distribution suggests that it may possibly occur in a range of reserves containing suitable rocky riparian habitat including Cuumbeun NR, northern Kosciuszko NP, Hattons Corner NR and Burrinjuck NP. This community was sampled and observed in a few TSRs.

Extent of clearing: Although restricted to moist riparian habitats, the rocky substrate of this type means it is unlikely to have been widely cleared.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u181: Community u181 on a scoured rocky bank of the Goobragandra River (plot UMC414), with a diverse array of shrubs, sedges, grasses and forbs surviving in skeletal soil pockets, dominated by *Callistemon sieberi*.

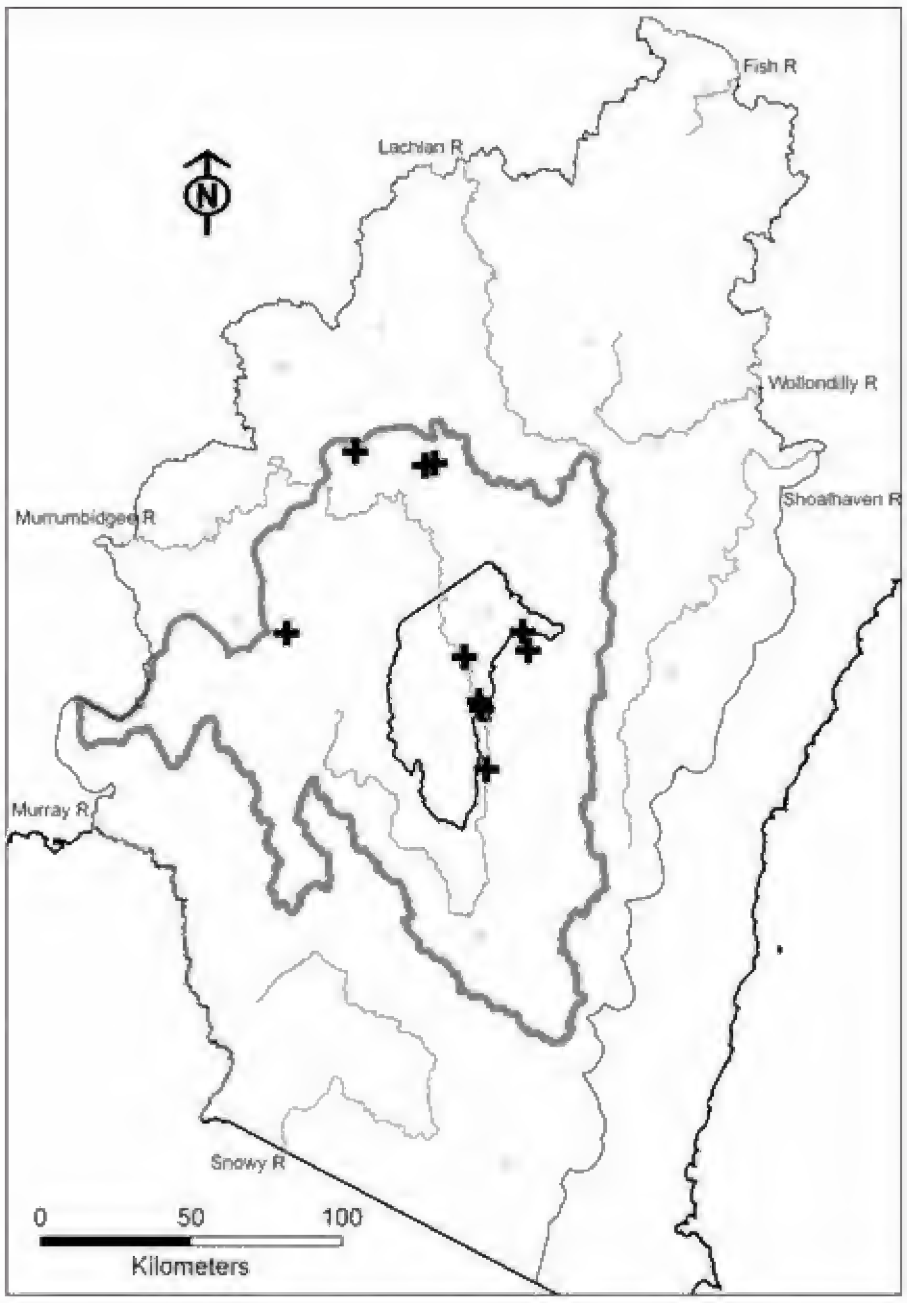

Fig. u181: Distribution of field samples assigned to this community.

Class: Inland Riverine Forests

u173: River Red Gum ± Apple Box very tall grass-forb riparian woodland on alluvial flats in the South Eastern Highlands and upper South Western Slopes bioregions

Scientific Name: *Eucalyptus camaldulensis* ± *Eucalyptus bridgesiana / Carex appressa – Geranium solanderi – Themeda australis – Microlaena stipoides – Lythrum hyssopifolia*

Number of samples:	6
Richness [mean (±SD)]:	16 (10)
Slope (degrees):	(1) 2–8 (13)
Altitude (m asl):	(286) 451–570 (769)
Ave. Annual Rainfall (mm):	(643) 654–753 (867)
Temp. Annual Range (°C):	(26.6) 26.7–27.8 (27.8)

Vegetation Description: Community u173 is a woodland to open forest characterised by an open, tall to very tall canopy of *Eucalyptus camaldulensis* and/or *Eucalyptus bridgesiana* above occasional scattered tall shrubs of *Acacia deanei.* A moderately dense, moist groundlayer commonly includes patches of grasses such as *Themeda australis*, *Microlaena stipoides* and *Rytidosperma racemosum* and forbs including *Lythrum hyssopifolia*, *Geranium solanderi* and *Rumex brownii*. Streambanks and overflow pools often support tall clumps of *Carex appressa*, *Juncus gregiflorus* and *Typha domingensis*, while calmer pools and wet exposed muddy banks may contain *Myriophyllum crispatum* and other aquatic plants.

This community is found on moderately fertile alluvial flats of meandering creeks and rivers of the western tablelands and upper slopes. It has been very widely cleared and remnants are often heavily disturbed. In the current study, based on only six survey plots, it is recorded along tributaries of the upper Lachlan River (at Lade Vale, Rye Park and Wheeo Creek) and the Murrumbidgee River (sampled on Yass River flats near Murrumbateman and a Tumut River tributary at Brungle, and observed on Jugiong Creek at Childowla Road TSR).

Within its range, Community u173 may be replaced by Community u181 [*Callistemon sieberi – Kunzea ericoides rocky riparian tall shrubland in the South Eastern Highlands and upper South Western Slopes bioregions*] in confined reaches of streams where alluvium is reduced to skeletal pockets over bedrock. On sections of stream with increased flow velocity and sand/gravel/cobble alluvium, it may be replaced by Community p32d [*Casuarina cunninghamiana dry forest on sand/gravel alluvial soils along major watercourses of the South Eastern Highlands and upper South Western Slopes bioregions*]. On riparian flats of the lower slopes and plains to the west of the current study area, Community u173 will grade into other River Red Gum dominated communities, such as the *River Red Gum Forest* described by Mulvaney *et al.* (2005) from Gundagai Shire.

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia deanei	1	33	1	1	P
Carex appressa	2	100	1	7	P
Eucalyptus bridgesiana	3	50	3	7	P
Eucalyptus camaldulensis	4	83	3	<1	P
Juncus gregiflorus	2	33	1	<1	P
Lythrum hyssopifolia	1	50	1	<1	P
Myriophyllum crispatum	2	33	2	<1	P
Typha domingensis	1	33	3	<1	P
Geranium solanderi	2	50	1	19	C
Microlaena stipoides	2	50	2	34	C
Themeda australis	2	50	2	21	C

Threatened communities: Nil, although it is highly rare / threatened within the region and may be eligible for listing.

Equivalent vegetation types: Plots allocated to this type include both plots within the broader analysis area classified by Gellie (2005) as VG43 [*Western Slopes Riparian Moist Sedge Woodland*], to which Community u173 has some affinities. It also has some affinities with VCA 79 [*River Red Gum shrub/grass riparian tall woodland or open forest wetland mainly in the Upper Slopes subregion of the NSW South Western Slopes bioregion and western South East Highlands bioregion*] (Benson *et al.* 2010).

Frequently occurring weeds: This community is restricted to moist, moderately fertile alluvial soils and is often heavily grazed and subject to occasional flooding disturbance, so is prone to invasion by a wide variety of exotic plant species. The following exotic plant species were recorded from 30% or more of the plots assigned to this type: *Acetosella vulgaris* (0.50), *Bromus diandrus* (0.33), *Bromus hordeaceus* (0.33), *Cirsium vulgare* (0.33), *Cynosurus echinatus* (0.50), *Holcus lanatus* (0.83), *Hypochaeris radicata* (0.50), *Lolium perenne* (0.33), *Paspalum dilatatum* (0.50), *Phalaris aquatica* (0.50), *Rosa rubiginosa* (0.33), *Rubus fruticosus* spp. agg. (0.33), *Rumex crispus* (0.33) and *Trifolium campestre* (0.33). Streambanks throughout much of the original extent of this type have been invaded by or are planted with exotic willow trees (*Salix* spp.).

Threats: The productive alluvial flats occupied by this community have been very widely cleared and converted to exotic pasture and/or are regularly cropped. Many surviving remnants are likely to be subject to ongoing stock grazing and invasion by weeds. Changes to stream hydrology in some catchments resulting from dams, changed runoff rates and bed-lowering may lead to long-term shifts in the composition of remnants of this community.

Reservation status: Only one plot assigned to this community is located in a conservation reserve (Burrinjuck NR). This community was also sampled and observed in a few TSRs.

Extent of clearing: Whilst limited in natural distribution, this community has been very widely cleared for agricultural development.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Mulvaney, M., Boak, M., Priday, S., Hudson, K. & Crane, M. (2005) The native vegetation of Gundagai shire. NSW Department of Environment and Conservation, Queanbeyan.

Plate u173: Community u173 as a narrow band of *Eucalyptus camaldulensis* over *Poa labillardierei* var. *labillardierei* and various sedges, on alluvial sediments along the Yass River at the Greenwood Road crossing (plot UMC405).

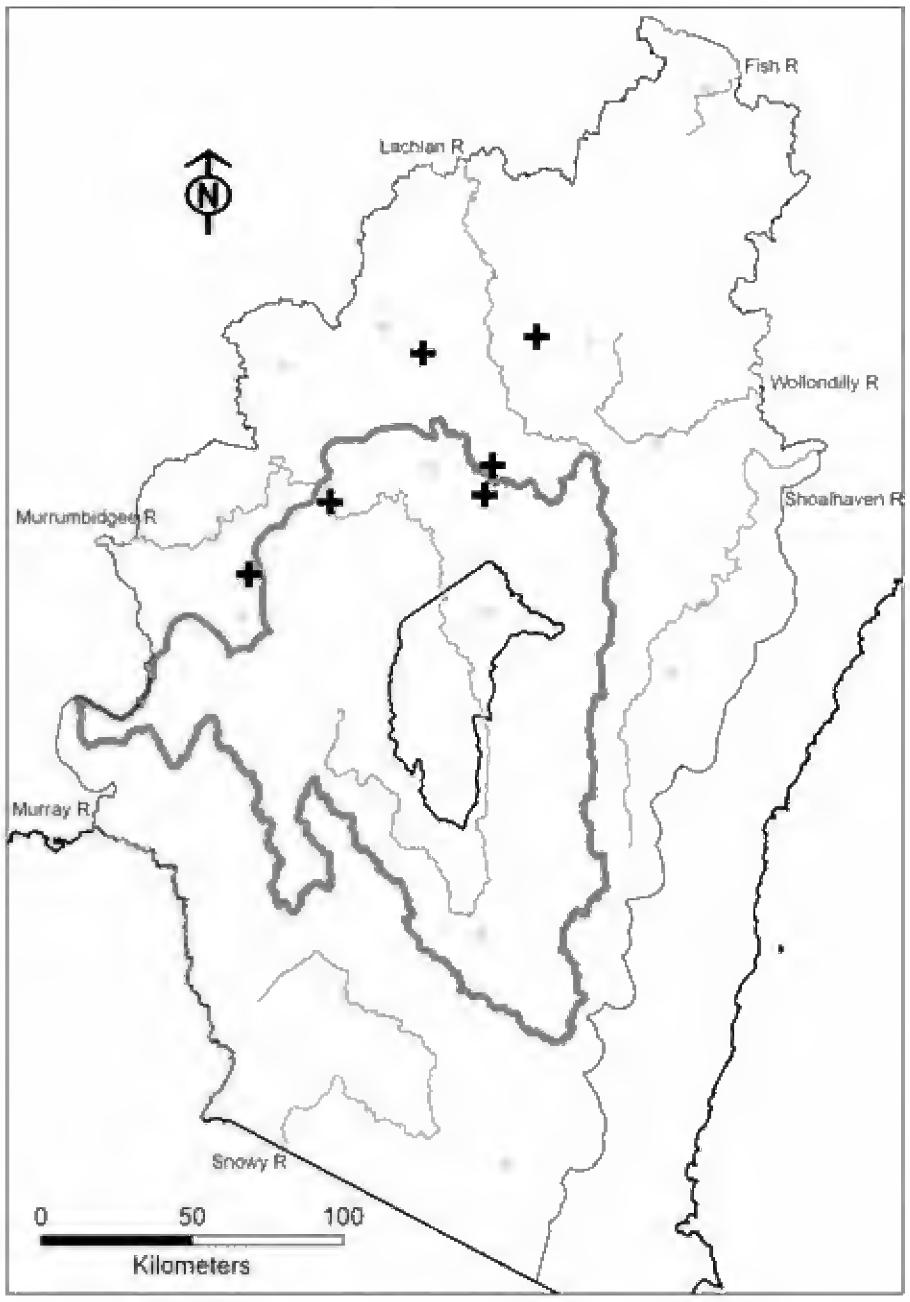

Fig. u173: Distribution of field samples assigned to this community.

Formation: Freshwater Wetlands

Class: Montane Bogs and Fens

a9: *Carex gaudichaudiana – Ranunculus amphitrichus – Phragmites australis* aquatic herbfield of waterways in the Australian Alps and South Eastern Highlands bioregions

Scientific Name: *Carex gaudichaudiana – Ranunculus amphitrichus – Carex appressa – Phragmites australis – Hydrocotyle tripartita – Epilobium pallidiflorum – Lythrum salicaria*

Number of samples:	6
Richness [mean (±SD)]:	9 (3)
Slope (degrees):	(0) 0–1 (2)
Altitude (m asl):	(975) 978–1065 (1150)
Ave. Annual Rainfall (mm):	(772) 978–1304 (1366)
Temp. Annual Range (°C):	(24.2) 25.2–25.6 (26.5)

Vegetation Description: Community a9 is a highly variable aquatic herbfield community that, with further sampling, may represent more than one community. It includes true aquatic species with fully submerged (e.g. *Myriophyllum alpinum*), floating (e.g. *Nymphoides montana*) or emergent foliage (e.g. *Carex gaudichaudiana*), as well as semi-aquatic species capable of growing as submergents for extended periods (e.g. *Lilaeopsis polyantha*, *Lythrum salicaria*, *Montia australasica*, *Ranunculus pimpinellifolius*). *Phragmites australis* or *Carex gaudichaudiana* may fringe such vegetation. Plant cover is sporadic and sometimes only one or a few species will be present.

This community occurs in and adjacent to permanent waterways (e.g. upper reaches of the Murrumbidgee River and its tributaries), in deeper pools along intermittent streams (e.g. Nungar Creek and McPhersons Plain in NSW, Sheep Station Creek and Grassy Creek in the ACT, and in Victoria), and broad flooded creek flats (e.g. Micalong Swamp in Bondo SF).

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Carex appressa	2	50	1	7	P
Carex gaudichaudiana	5	100	2	4	P
Epilobium pallidiflorum	2	33	2	<1	P
Hydrocotyle tripartita	3	33	2	<1	P
Lilaeopsis polyantha	1	33	2	<1	P
Lythrum salicaria	2	33	2	<1	P
Montia australasica	2	33	1	1	P
Myriophyllum variifolium	2	33	1	<1	P
Phragmites australis	2	50	2	<1	P
Ranunculus amphitrichus	3	67	1	<1	P
Ranunculus pimpinellifolius	1	33	1	1	P
Stellaria angustifolia	2	33	1	2	P

Threatened communities: Nil.

Equivalent vegetation types: Community 9 [*Aquatic*] (McDougall & Walsh 2007).

Frequently occurring weeds: Weeds are generally not prevalent in this community, suggesting a high degree of ecosystem stability. Even so, the moisture dependent *Holcus lanatus* (0.33), *Myosotis discolor*

Plate a9: Dense *Carex gaudichaudiana* with occasional patches containing a diversity of floating and submerged aquatic plants is typical of Community a9. In this example at Micalong Swamp (plot UMC416), patches of *Potamogeton tricarinatus* can be seen.

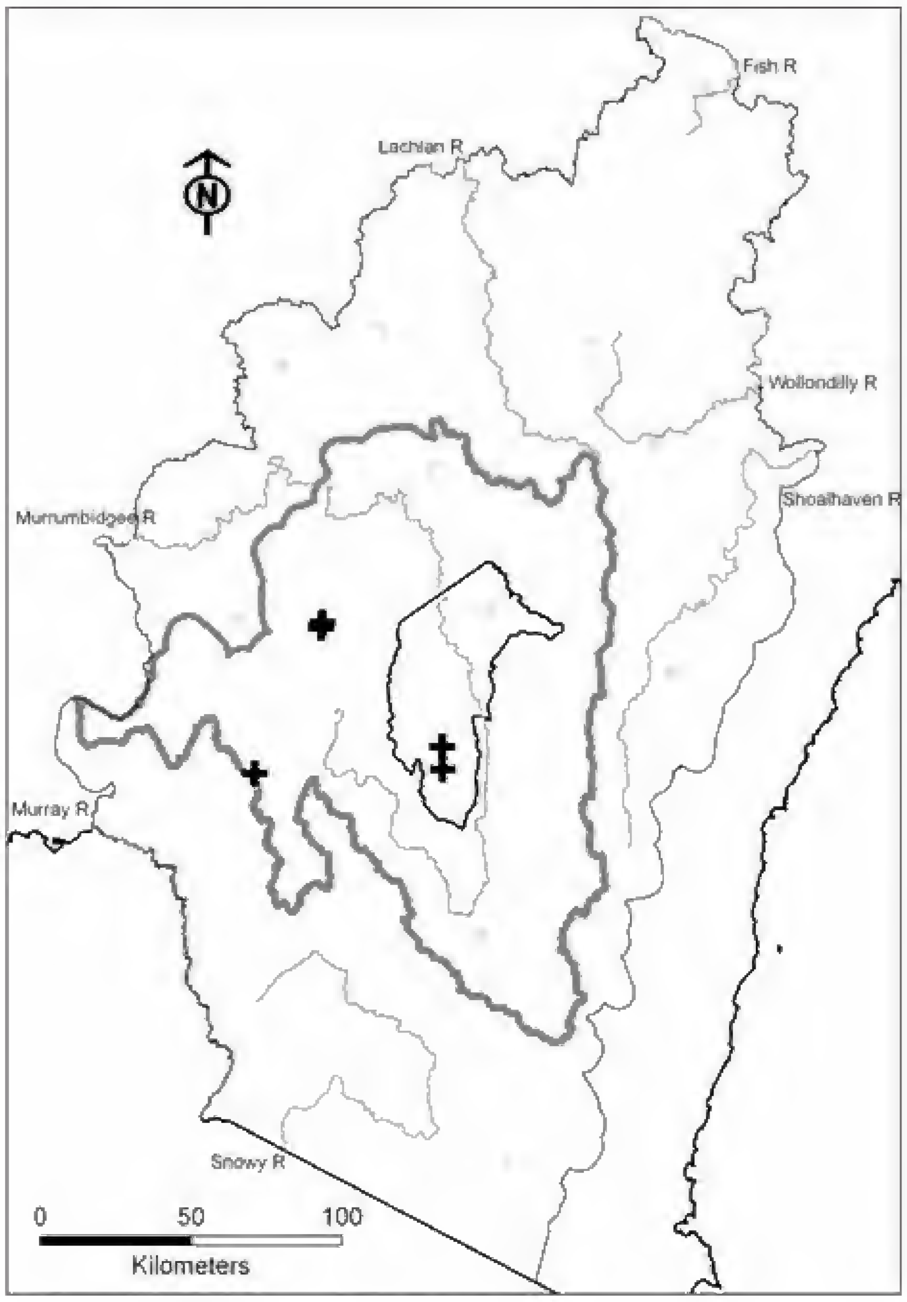

Fig. a9: Distribution of field samples assigned to this community.

Plate e59: Scattered *Hakea microcarpa* and *Baeckea utilis* growing amongst *Empodisma minus* and a diversity of moisture-loving herbs is typical of Community e59, as with this example (plot UMC024B) at the headwaters of Roberts Ck, Tinderry NR.

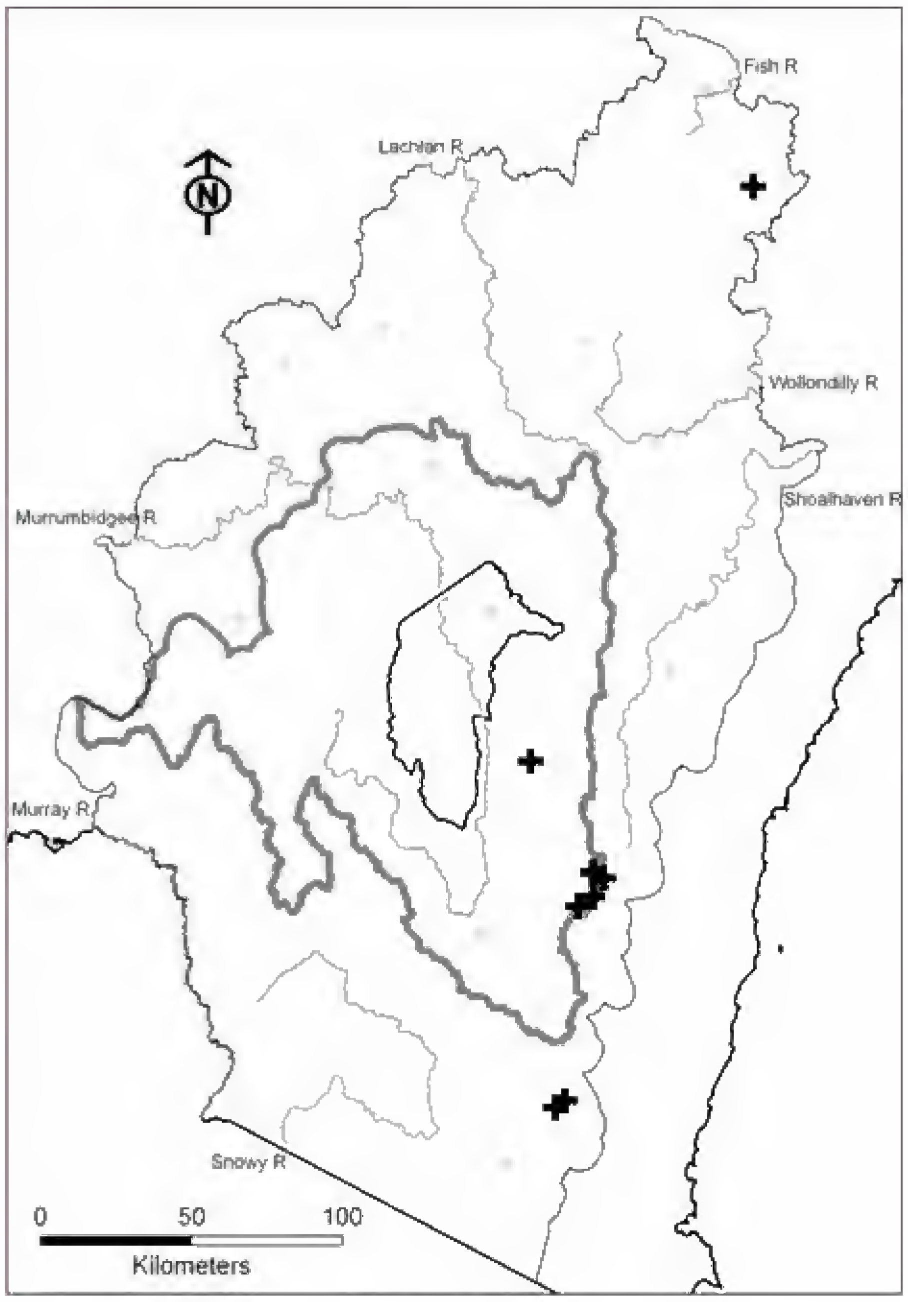

Fig. e59: Distribution of field samples assigned to this community.

(0.33) and *Myosotis laxa* subsp. *caespitosa* (0.5) were recorded in a reasonable number of plots.

Threats: Some trampling of creek edges by horses has been observed in the vicinity of this community. It is possible however that some sites formerly supporting this community have been degraded by past domestic grazing to the extent that they are no longer floristically analogous. The weed *Myosotis laxa* subsp. *caespitosa* is locally dominant in some examples (e.g. Cooleman Plain in Kosciuszko NP and McPhersons Plain east of Tumbarumba) and may threaten the integrity of this community. Flood events and drought presumably lead to great fluctuation in species composition over time. The effect of deliberate large releases of water for environmental flows from Tantangara Dam is unknown but worth investigating, as the community is well developed below the dam. The establishment of commercial timber plantations in the catchment of these sites also has the potential to compromise their hydrology.

Reservation status: Present in Kosciuszko NP and Namadgi NP, with non-reserved examples being on State Forest and freehold land.

Extent of clearing: Unknown.

References: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

e59: *Hakea microcarpa – Baeckea utilis – Leptospermum myrtifolium* subalpine wet heathland on escarpment and eastern tableland ranges of the South Eastern Highlands bioregion

Scientific Name: *Hakea microcarpa – Baeckea utilis – Leptospermum myrtifolium – Epacris breviflora / Empodisma minus – Hydrocotyle sibthorpioides – Baloskion australe – Hypericum japonicum*

Number of samples:	10
Richness [mean (±SD)]:	28 (7)
Slope (degrees):	(0) 1–4 (6)
Altitude (m asl):	(937) 953–1059 (1187)
Ave. Annual Rainfall (mm):	(747) 958–1047 (1082)
Temp. Annual Range (°C):	(22.6) 23.6–24.2 (25)

Vegetation Description: Community e59 is a sub-alpine bog heathland characterised by an open (to occasionally closed) shrub stratum to approximately 1.5 metres tall, commonly dominated by *Baeckea utilis*, *Leptospermum myrtifolium* and *Epacris paludosa* and comprising many other species commonly found in the community of similar landscape position in the Australian Alps bioregion [i.e. Community a2: *Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*], such as *Carex gaudichaudiana*, *Epacris breviflora*, *Empodisma minus*, *Luzula modesta* and *Oreomyrrhis ciliata*. *Sphagnum cristatum* often occurs as isolated clumps beneath shrubs or at the margins where a permanent supply of water permits. The community is often fringed by eucalypts (e.g. *Eucalyptus dalrympleana*, *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus stellulata*), and moisture-loving grasses such as *Poa labillardierei* may be locally abundant.

This community occurs on peats and humified peat soils developed on alluvium in the bottoms of broad, flat valleys along the Great Dividing Range and coastal escarpment ranges. It may extend westward into the ACT (G. Baines, ACT ESDD, pers. comm.).

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Allittia cardiocarpa	1	30	1	<1	P
Asperula gunnii	2	50	1	5	P
Baeckea utilis	3	70	2	1	P
Baloskion australe	3	60	1	2	P
Brachyscome scapigera	2	30	1	2	P
Carex spp.	3	30	1	2	P
Cotula alpina	1	50	1	1	P
Craspedia variabilis	2	50	1	5	P
Empodisma minus	3	80	2	3	P
Epacris breviflora	2	50	1	2	P
Epacris microphylla	2	20	1	1	P
Epacris paludosa	2	40	2	1	P
Geranium neglectum	2	40	2	2	P
Gonocarpus micranthus	2	40	1	2	P
Hakea microcarpa	2	100	1	3	P
Hookerochloa hookeriana	5	20	1	<1	P
Hydrocotyle sibthorpioides	3	80	2	4	P
Hypericum japonicum	2	60	1	3	P
Hypoxis hygrometrica	2	20	1	<1	P
Juncus sarophorus	2	40	1	<1	P
Leptospermum continentale	1	30	1	2	P
Leptospermum myrtifolium	2	70	1	3	P
Lindsaea linearis	1	20	1	<1	P
Luzula modesta	1	30	1	2	P
Mitrasacme serpyllifolia	2	60	1	<1	P
Oreobolus oxycarpus subsp. *oxycarpus*	3	20	1	<1	P
Oreomyrrhis ciliata	1	40	1	2	P
Patersonia fragilis	2	20	2	<1	P
Ranunculus pimpinellifolius	2	40	1	1	P
Stackhousia viminea	2	20	1	<1	P
Stellaria angustifolia	1	30	1	1	P
Utricularia dichotoma	2	20	1	<1	P
Velleia montana	1	40	1	<1	P
Veronica subtilis	2	20	1	<1	P
Viola caleyana	1	30	1	<1	P
Xerochrysum palustre	3	20	1	1	P
Euchiton japonicus	1	40	1	15	C
Poa labillardierei	4	40	2	10	C

Threatened communities: TSC Act 1995 – *Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions.*

Equivalent vegetation types: Related to FrWe59 [*Southeast Sub-alpine Bog*] (Tozer *et al.* 2010) and Floristic Group 4 [*Shrubby herbaceous Sphagnum peatlands*] (Whinam & Chilcott 2002).

Frequently occurring weeds: The presence of domestic stock in sites on freehold and State Forest land is the likely cause of weed invasion in the community. Many sites within the conservation reserve system were also historically grazed, with the legacy of that land management expressed through the continued presence of exotic plant species. The most commonly recorded species in this community were *Cirsium vulgare* (0.40), *Hypochaeris radicata* (0.50), *Taraxacum officinale* (0.30) and *Trifolium repens* (0.30).

Threats: Some examples on State Forest and freehold land are grazed by cattle. This community is especially sensitive to trampling damage and further degradation can be expected on these tenures. Grazing, trampling and wallowing by deer occurs on all tenures but the degree of this disturbance is unknown. Frequent burning may destroy this community by damaging *Sphagnum* and peats, which causes drying of the soil and is likely to lead to the establishment of species more commonly found on drier sites. Rooting by feral pigs disturbs the groundlayer, and is associated with declining local populations of some species as well as the incursion of exotic plant species.

Reservation status: Likely to be approximately evenly distributed in National Parks and Nature Reserves, State Forest and freehold. Recorded from survey plots in Badja Swamps NR, Deua NP, Kanangra-Boyd NP and South East Forest NP.

Extent of clearing: Tozer *et al.* (2010) indicate that about 70% of this community has been cleared or heavily degraded by grazing.

References: Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406; Whinam, J. & Chilcott, N. (2002) Floristic description and environmental relationships of *Sphagnum* communities in NSW and the ACT and their conservation management. *Cunninghamia* 7:463–500.

Plate u193: Community u193 with *Hakea microcarpa*, *Baeckea utilis* and *Carex gaudichaudiana* in Yaouk Creek Swamp, Scabby Range Nature Reserve (plot UMC421).

u193: *Hakea microcarpa – Epacris breviflora – Epacris paludosa* subalpine wet heathland of the Australian Alps and western South Eastern Highlands bioregions

Scientific Name: *Eucalyptus camphora* subsp. *humeana / Hakea microcarpa – Epacris breviflora – Epacris paludosa / Empodisma minus – Carex gaudichaudiana – Asperula gunnii – Gonocarpus micranthus*

Number of samples:	14
Richness [mean (±SD)]:	28 (7)
Slope (degrees):	(0) 1–8 (13)
Altitude (m asl):	(790) 1002–1188 (1439)
Ave. Annual Rainfall (mm):	(847) 936–1331 (1495)
Temp. Annual Range (°C):	(23) 23.8–25.6 (26)

Vegetation Description: Community u193 is a swampy heathland to 2 metres in height, typically dominated by *Baeckea utilis*, *Epacris breviflora*, *Epacris paludosa* and/or *Hakea microcarpa*. The ground cover is usually a dense cover of *Empodisma minus* and sedges (*Carex* spp., *Eleocharis* spp.) interspersed with herbs such as *Gonocarpus micranthus*, *Hydrocotyle sibthorpioides*, *Poa costiniana*, *Poa labillardierei* and *Ranunculus pimpinellifolius. Carex gaudichaudiana* may be abundant in areas of open water within the community. *Sphagnum cristatum* may also be present.

This community is distributed between the Brindabella Ranges and the Tumbarumba area. It is largely a treeless, shrub-dominated wetland apart from scattered or fringing *Eucalyptus camphora* subsp. *humeana* to 5 metres in height at some sites. Floristically and structurally it is similar to low altitude examples of Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*], which typically occurs on broad frost hollows where it is bordered by grassland. Upslope, this community adjoins woodland or forest dominated by *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus stellulata* or *Eucalyptus dalrympleana*. Examples range in size from tens of square metres where fed by permanent springs to several hectares on flat sections of streams. Soils are peaty.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Asperula gunnii	2	71	1	5	P
Baeckea gunniana	2	21	1	1	P
Baeckea utilis	3	57	2	1	P
Baloskion australe	2	64	1	2	P
Brachyscome scapigera	1	21	1	2	P
Carex appressa	2	50	1	7	P
Carex gaudichaudiana	3	79	2	4	P

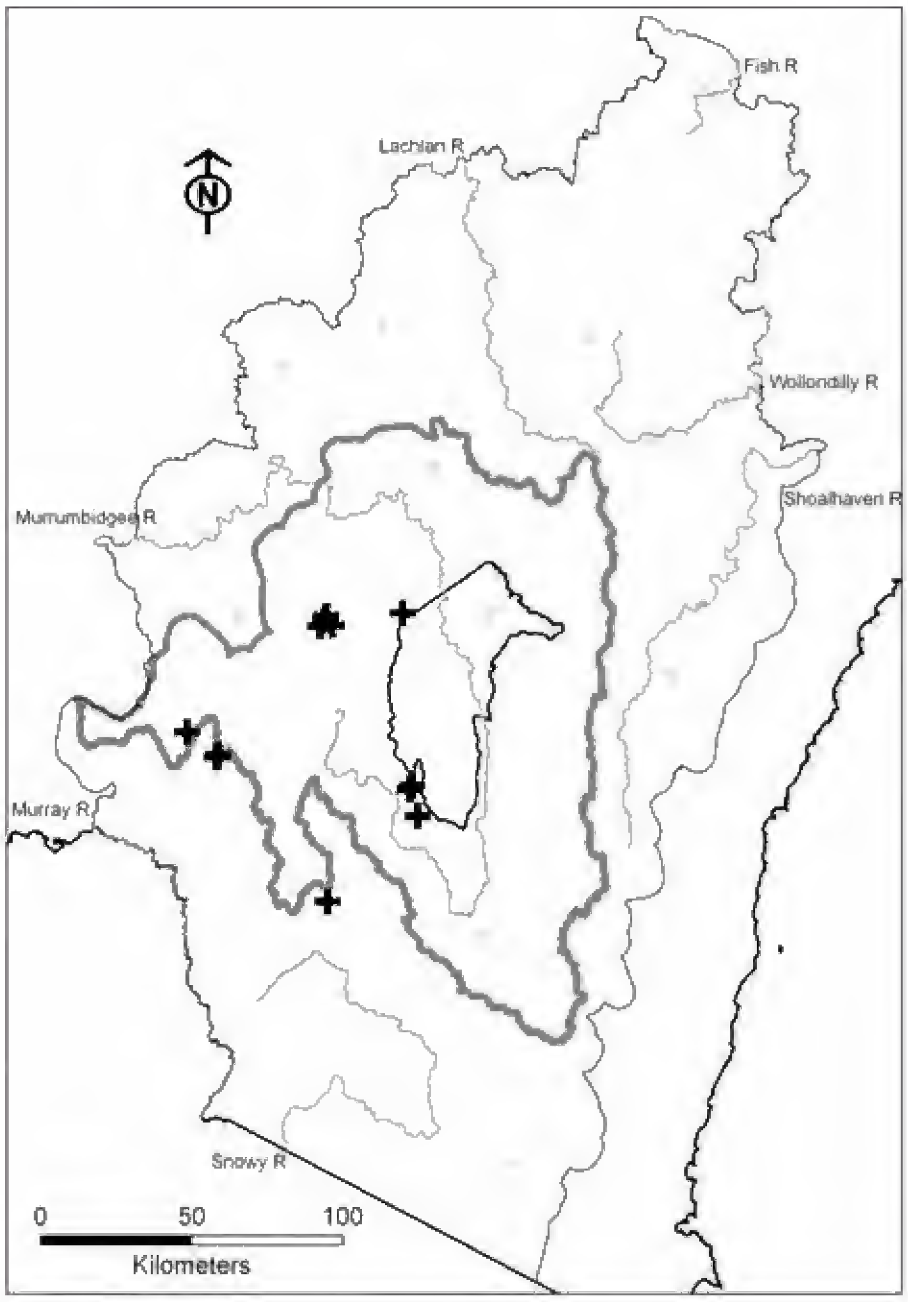

Fig. u193: Distribution of field samples assigned to this community.

Comesperma retusum	1	36	1	<1	P
Deyeuxia gunniana	2	21	1	<1	P
Eleocharis gracilis	2	29	2	<1	P
Eleocharis sphacelata	2	21	3	<1	P
Empodisma minus	4	71	2	3	P
Epacris breviflora	2	86	1	2	P
Epacris paludosa	3	57	2	1	P
Epilobium billardierianum subsp. *hydrophilum*	2	21	1	<1	P
Epilobium gunnianum	1	21	1	1	P
Eucalyptus camphora subsp. *humeana*	3	21	1	<1	P
Gonocarpus micranthus	2	71	1	2	P
Gratiola peruviana	2	29	1	1	P
Hakea microcarpa	2	86	1	3	P
Hydrocotyle algida	1	21	1	1	P
Hydrocotyle sibthorpioides	2	64	2	4	P
Hypericum japonicum	2	36	1	4	P
Hypoxis hygrometrica	2	21	1	<1	P
Juncus falcatus	1	21	1	<1	P
Juncus fockei	1	21	1	<1	P
Lachnagrostis filiformis	2	29	2	4	P
Lobelia pedunculata	2	29	1	5	P
Lobelia surrepens	2	21	2	<1	P
Luzula modesta	2	57	1	2	P
Luzula ovata	1	21	1	<1	P
Myriophyllum crispatum	2	21	2	<1	P
Oreomyrrhis ciliata	2	21	1	2	P
Pimelea bracteata	2	36	1	<1	P
Poa costiniana	2	43	2	5	P
Poa labillardierei	2	43	2	10	P
Ranunculus pimpinellifolius	1	43	1	1	P
Senecio glomeratus	2	21	2	<1	P
Stellaria angustifolia	2	43	1	1	P
Veronica subtilis	2	50	1	<1	P

Threatened communities: TSC Act 1995 – *Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions.*

Equivalent vegetation types: Community u193 has an affinity with VG124 [*Western Montane/Sub-alpine Wet Heath/Herb Grass Woodland*] and includes western elements of VG123 [*Montane/Sub-alpine Wet Heath/Bog*] (Gellie 2005). The new community concept appears to be a largely treeless wetland (apart from scattered or fringing *Eucalyptus camphora* subsp. *humeana*) related to Community a2 [*Baeckea gunniana – Epacris paludosa – Richea continentis – Sphagnum cristatum wet heathland of the Australian Alps bioregion (Bog)*], which occurs mostly at higher altitude. Western examples may have some affinities with VCA 285 [*Broad-leaved Sally grass – sedge woodland on valley flats and swamps in the NSW South-western Slopes and adjoining South Eastern Highlands bioregions*] (Benson *et al.* 2010).

Frequently occurring weeds: Disturbance by cattle (whether historic or more recent) is the likely reason for the high frequency with which some weeds were recorded from this community. As with other freshwater wetland communities, *Holcus lanatus* (0.75), *Hypochaeris radicata* (0.50) and *Trifolium repens* (0.33) were the most frequently recorded weeds.

Threats: All examples are threatened by feral horse grazing and trampling. Cattle grazing is permitted in many State Forest examples. Although most vascular plants in this community are facultative resprouters and well-adapted to fire, *Sphagnum cristatum* and the peat soils beneath may be damaged by single fire events. Additionally, fire regimes that repeatedly cause such damage before natural recovery occurs will destroy the system through drying, which facilitates stream entrenchment and allows species of drier systems to invade. Low montane wetlands are far more susceptible to weed invasion than similar systems at high altitude. Exotic grasses such as *Holcus lanatus* can become abundant and dominating following disturbance. Exotic *Juncus* species (e.g. *Juncus effusus*, *Juncus articulatus*) and *Salix cinerea* may be future threats to the integrity of this community.

Reservation status: Recorded in Brindabella NP, Scabby Range NR, Yaouk NR and the western edge of Kosciuszko NP, but mostly occurs in State Forest and on freehold land.

Extent of clearing: Unknown and probably negligible but all examples have a history of grazing, which is likely to have severely degraded this community.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Class: Montane Lakes

L12: Freshwater sedge-herb marsh of shallow, commonly inundated wetlands of the eastern South Eastern Highlands bioregion

Scientific Name: *Eleocharis acuta – Amphibromus nervosus – Lachnagrostis filiformis ± Eleocharis pusilla / Glossostigma elatinoides – Ranunculus inundatus – Hydrocotyle sibthorpioides / Myriophyllum simulans – Potamogeton tricarinatus*

Number of samples:	29
Richness [mean (±SD)]:	17 (6)
Slope (degrees):	(0) 0–1 (4)
Altitude (m asl):	(708) 773–1035 (1239)
Ave. Annual Rainfall (mm):	(530) 584–744 (879)
Temp. Annual Range (°C):	(24.1) 24.8–26.3 (26.8)

Vegetation Description: Community L12 occupies frequently-inundated wetlands and is commonly dominated by the tall emergent spike-sedge *Eleocharis acuta* accompanied by scattered *Amphibromus nervosus* and *Lachnagrostis filiformis.* A variety of other tall emergents present at varying frequency include *Eleocharis pusilla*, *Juncus australis*, *Eleocharis sphacelata* and/or *Carex tereticaulis*. Some new plots assigned to this group include *Triglochin procera* and *Glyceria australis,* at times as co-dominant emergents. A layer of low herbaceous wetland plants commonly sprawls along wetland margins, frequently dominated by *Hydrocotyle sibthorpioides*, *Glossostigma elatinoides* and *Ranunculus inundatus*, with a diversity of other low wetland forbs at lower frequencies on the margins and spreading across standing water by rhizomes or stolons. Standing water is commonly occupied by floating/submerged aquatic taxa *Myriophyllum simulans* and *Potamogeton tricarinatus* and less commonly *Potamogeton ochreatus*, *Myriophyllum caput-medusae*, and occasionally the tiny gypsy floaters *Azolla filiculoides*, *Lemna disperma* or *Wolffia australiana.*

Community L12 is generally known from alluvium derived from a variety of substrates including basalt, granite, granodiorite and sedimentary rocks. Most samples are from Monaro lakes, in an area bounded by Cootralantra in the north, Hilltop and Ingebirah in the west, south to Bombala and east to Nimmitabel. Recent plot samples extend the range of this tableland wetland complex far to the north, with samples from Molonglo Lagoon east of Queanbeyan, along the Collector Creek chain-of-ponds system above Lake George, from swamps at Rowes Lagoon and Wet Lagoon, and from Burra Burra Lake on basalt north of Taralga.

Also added to this group are plots from frequently-inundated river-flat wetlands on the Monaro – beside the Bombala River near Bibbenluke and the Murrumbidgee River east of Adaminaby.

This community is partly defined from whole-lake samples collected by Benson & Jacobs (1994) and is closely alligned with their Communities 1 and 2. The species list below is based on data from a combination of 22 whole-lake samples and seven plot samples assigned to this group.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Amphibromus nervosus	2	86	2	<1	P
Brachyscome radicans	2	21	1	<1	P
Carex tereticaulis	1	21	2	<1	P
Centipeda cunninghamii	2	31	3	<1	P
Crassula helmsii	2	38	3	<1	P
Eleocharis acuta	4	93	3	1	P
Eleocharis pusilla	3	48	2	<1	P
Eleocharis sphacelata	3	28	2	<1	P
Euchiton sphaericus	2	28	1	7	P
Glossostigma elatinoides	3	62	2	<1	P
Hydrocotyle sibthorpioides	3	72	2	4	P
Isolepis platycarpa	4	24	3	<1	P
Juncus australis	2	38	1	1	P
Juncus radula	2	31	1	<1	P
Lachnagrostis filiformis	3	83	1	4	P
Limosella australis	2	28	3	1	P
Lobelia surrepens	2	24	2	<1	P
Marsilea costulifera	3	34	3	<1	P
Montia australasica	1	24	1	1	P
Myriophyllum caput-medusae	3	21	3	<1	P
Myriophyllum simulans	4	66	2	<1	P
Persicaria prostrata	2	31	2	<1	P
Potamogeton ochreatus	2	28	3	<1	P
Potamogeton tricarinatus	3	79	4	<1	P
Ranunculus diminutus	2	24	3	1	P
Ranunculus inundatus	2	76	1	<1	P
Stellaria angustifolia	1	24	1	1	P

Threatened communities: EPBC Act 1999 – *Upland Wetlands of the New England Tablelands and the Monaro Plateau.*

Equivalent vegetation types: This community represents a revision of marsh communities 1 and 2 [*Shallow freshwater sedge-herb marshes*] identified by Benson & Jacobs (1994), with the extension of this combined type to the north with the addition of wetland plot samples from the broader Southern Tablelands, and into floodplain marshes. This community is related to FrWp57 [*Tableland Swamp Meadow*] identified by Tozer *et al.* (2010).

Frequently occurring weeds: The widespread aquatic weeds *Juncus articulatus* (0.45) and *Rumex crispus* (0.48) were the most common weeds observed in this community.

Threats: These shallow herbaceous tableland wetlands exist in specialised habitats of concentrated moisture and nutrients with high agricultural productivity potential. As such they have been subject to widespread, intensive disturbances including draining, exotic pasture introductions, heavy stock grazing and cropping. Remaining undrained examples located within highly modified rural catchments may be subject to increased frequency of eutrophication and invasion by exotic plants at various stages of their wetting/drying cycles.

Reservation status: No records of this community occur on conservation reserves.

Extent of clearing: The original extent of these herbaceous wetlands is likely to have been greatly reduced across their range by widespread draining, cropping and exotic pasture establishment.

Plate L12: Community L12 on Molonglo Lagoon north of Hoskinstown (plot UMC419) dominated by *Eleocharis acuta* and *Schoenoplectus pungens* over floating/submerged aquatic species.

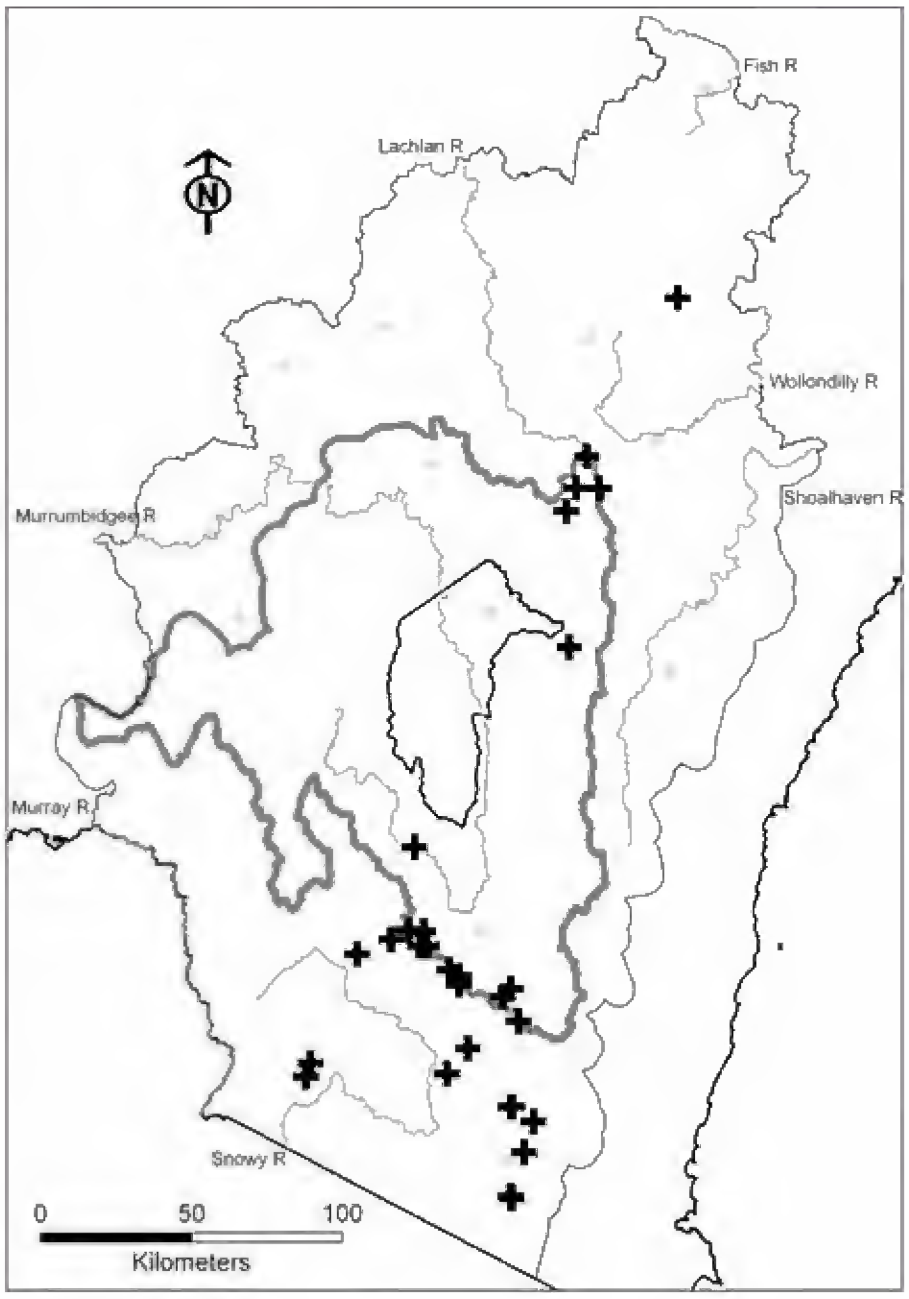

Fig. rL12: Distribution of field samples assigned to this community

References: Benson, J.S. & Jacobs, S.W.L. (1994) Plant communities of the Monaro lakes. *Cunninghamia* 3: 651–676; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

L3: Freshwater sedge-herb marsh of shallow ephemeral lakes of the eastern South Eastern Highlands bioregion

Scientific Name: *Lachnagrostis filiformis – Eleocharis acuta – Isolepis platycarpa / Centipeda cunninghamii – Limosella australis – Persicaria prostrata* ± *Ranunculus diminutus / Potamogeton ochreatus* ± *Potamogeton tricarinatus*

Number of samples:	13
Richness [mean (±SD)]:	10 (4)
Slope (degrees):	(0) 0–1 (4)
Altitude (m asl):	(744) 916–1003 (1012)
Ave. Annual Rainfall (mm):	(512) 521–586 (758)
Temp. Annual Range (°C):	(24.6) 25.5–26.6 (27.1)

Vegetation Description: Community L3 is recorded from shallow lakes formed on basalt substrates on the Monaro. Although only sampled from the Monaro, other small ephemeral wetlands matching this community may occur (or occurred prior to dusturbance) further north along the tablelands, for example smaller lakes/lagoons in the Lake Bathurst and Breadalbane areas.

This community is recorded from lakes which are generally small in area, shallow and ephemeral (“*probably dry for most of the year*” – Benson & Jacobs 1994), and some may be moderately saline. Common dominant native plants are ubiquitous, resilient perennial wetland species including the tufted plants *Eleocharis acuta*, *Lachnagrostis filiformis* and *Isolepis platycarpa*, prostrate forbs such as *Centipeda cunninghamii*, *Limosella australis* and *Persicaria prostrata*, and the highly vagile annual aquatic pondweed *Potamogeton ochreatus*. These wetlands tend to have relatively low native species richness.

Community L3 is defined entirely from whole-lake samples collected by Benson & Jacobs (1994) and therefore is closely alligned with Community 3 as described in that study.

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Amphibromus nervosus	3	31	2	<1	P
Carex bichenoviana	2	23	3	<1	P
Centipeda cunninghamii	3	92	2	<1	P
Crassula helmsii	2	38	3	1	P
Eleocharis acuta	2	77	3	2	P
Eleocharis pusilla	3	31	2	<1	P
Glossostigma elatinoides	2	23	3	<1	P
Isolepis platycarpa	3	77	3	<1	P
Lachnagrostis filiformis	3	100	2	4	P
Limosella australis	2	77	3	1	P
Marsilea costulifera	5	31	2	<1	P
Myriophyllum verrucosum	4	31	3	<1	P
Persicaria prostrata	2	54	2	<1	P
Potamogeton ochreatus	3	54	2	<1	P
Potamogeton tricarinatus	4	46	3	<1	P
Puccinellia stricta	2	23	2	<1	P
Ranunculus diminutus	3	38	2	1	P

Plate L3: An inundated example of Community L3 in a basalt depression on Maffra Road approximately 16 km south of Cooma. This photo was taken in the same location as plot MWP166, although almost 20 years later.

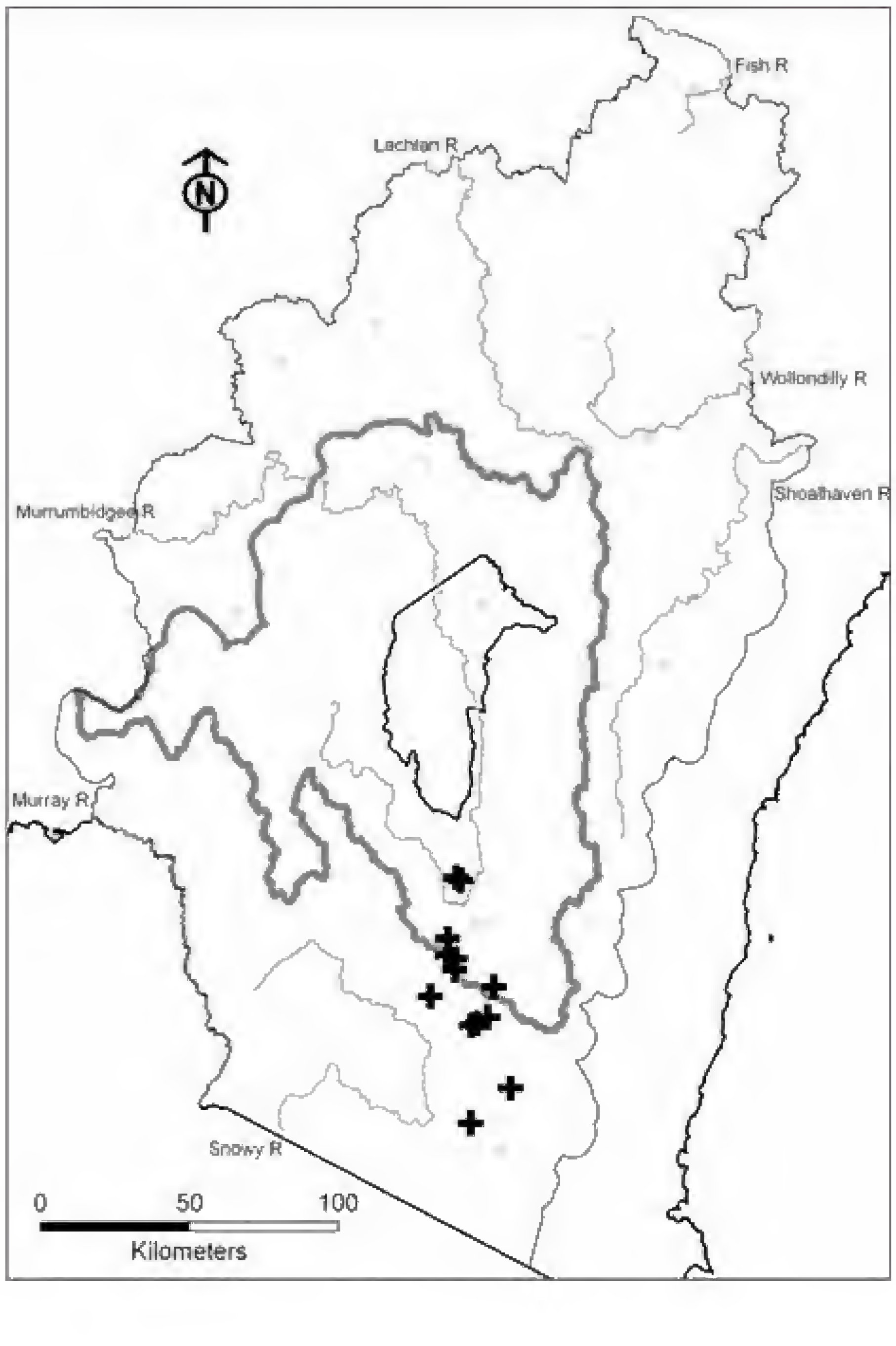

Fig. L3: Distribution of field samples assigned to this community.

Threatened communities: EPBC Act 1999 – *Upland Wetlands of the New England Tablelands and the Monaro Plateau.*

Equivalent vegetation types: Equivalent to Community 3 [*Shallow ephemeral freshwater herb-grass marsh*] of Benson & Jacobs (1994).

Frequently occurring weeds: The weed species recorded from within this community are typical of degraded moist–terrestrial and ephemeral-aquatic environments, and include *Holcus lanatus* (0.31), *Persicaria maculosa* (0.31), *Rumex crispus* (0.23) and *Veronica anagallis-aquatica* (0.23).

Threats: These ephemeral herbaceous tableland lakes are specialised habitats of concentrated moisture and nutrients with high agricultural productivity potential, so have been subject to widespread, intensive disturbances equivalent to clearing including draining, exotic pasture plant introductions, heavy stock grazing and cropping. Remaining undrained examples located within highly modified rural catchments may be subject to increased frequency of eutrophication and invasion by exotic plants at various stages of their wetting/drying cycles.

Reservation status: No records of this community occur on conservation reserves.

Extent of clearing: The original extent of these herbaceous wetlands is likely to have been greatly reduced across their range by widespread draining, cropping and exotic pasture establishment.

Reference: Benson, J.S. & Jacobs, S.W.L. (1994) Plant communities of the Monaro lakes. *Cunninghamia* 3: 651–676.

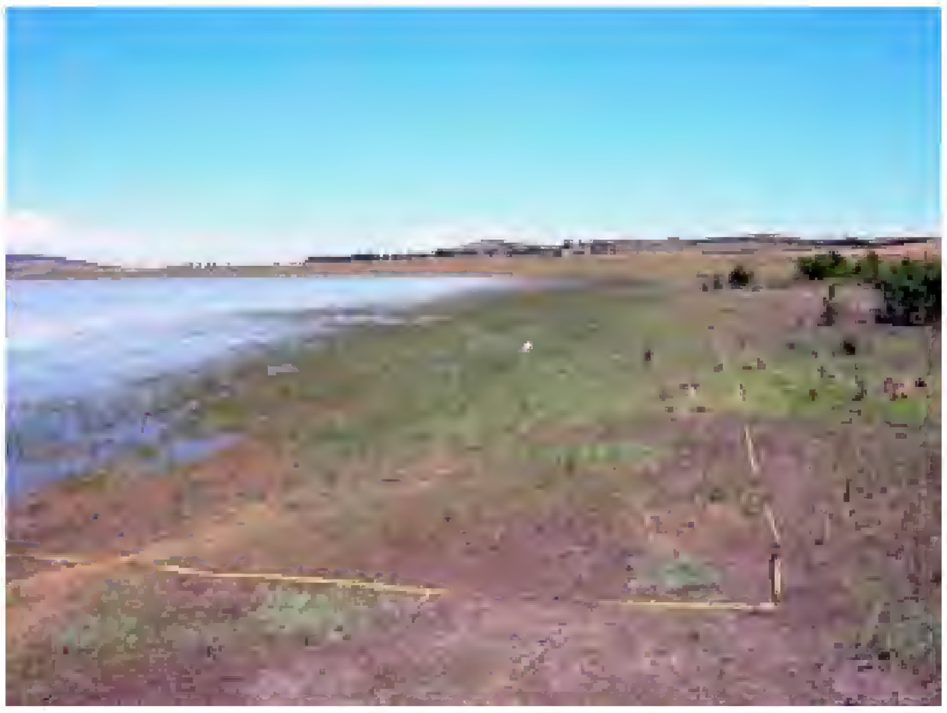

Plate L4: Community L4 on the Little Morass, adjoining the Morass and Lake Bathurst, with the drying lake margin supporting a diverse suite of wetland and moist edge species (plot KT_LAKBB).

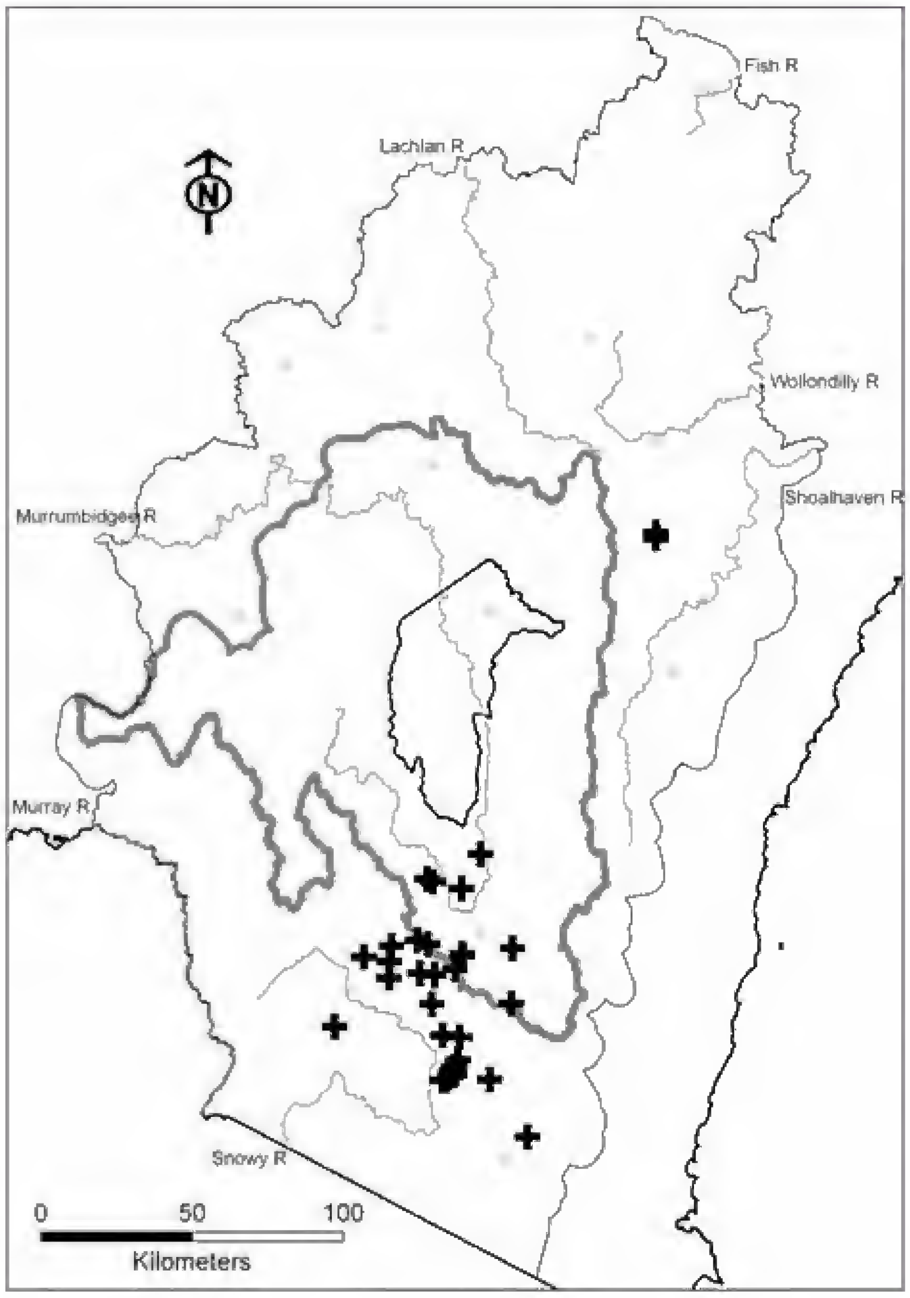

Fig. L4: Distribution of field samples assigned to this community.

L4: Freshwater sedge-herb marsh of deep semi-permanent and/or slightly saline wetlands of the eastern South Eastern Highlands bioregion

Scientific Name: *Lachnagrostis filiformis – Carex bichenoviana – Eleocharis acuta ± Eleocharis pusilla / Ranunculus diminutus – Limosella australis – Crassula helmsii ± Persicaria prostrata / Lepilaena bilocularis*

Number of samples:	32
Richness [mean (±SD)]:	13 (5)
Slope (degrees):	(0) 0–0 (4)
Altitude (m asl):	(672) 874–987 (1165)
Ave. Annual Rainfall (mm):	(505) 531–650 (799)
Temp. Annual Range (°C):	(24.5) 25.7–26.7 (27.6)

Vegetation Description: Tableland lakes containing community L4 are generally large in area, deep and contain permanent water (“*rarely dry*”) (Benson & Jacobs 1994). Some are moderately saline at least during drying phases. Common native species of these wetlands and their margins include tall emergents *Eleocharis acuta*, *Carex bichenoviana*, *Lachnagrostis filiformis* and *Juncus vaginatus*, a mixed low forbs layer including *Crassula helmsii*, *Limosella australis*, *Ranunculus diminutus* and *Persicaria prostrata*, and aquatic taxa commonly dominated by the submerged *Lepilaena bilocularis*.

This community occurs on alluvium derived from a variety of substrates including basalt, granite, granodiorite and sedimentary rocks. Monaro Lake samples range from Dangelong, Bililingra and Dry Plain in the north, southwest to Cootralantra, Hill Top and Moonbah, and east to Bungarby, Bibbenluke and Rock Flat. Recent plot samples from the Morass and little Morass (beside Lake Bathurst) extend the range of this wetland complex far to the north. This type may also occur on other large but currently unsampled tableland lakes including some of those in the Breadalbane area.

Community L4 is largely defined from whole-lake samples collected by Benson & Jacobs (1994) and is closely alligned with Community 4 as described in that study. The species list below is based on data from a combination of 29 whole-lake samples and three plot samples assigned to this group.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Carex bichenoviana	3	84	2	<1	P
Carex tereticaulis	3	34	1	<1	P
Chenopodium glaucum	2	31	3	<1	P
Crassula helmsii	3	75	2	<1	P
Eleocharis acuta	3	72	3	1	P
Eleocharis pusilla	2	41	2	<1	P
Hydrocotyle sibthorpioides	2	25	2	4	P
Isolepis platycarpa	3	22	3	<1	P
Juncus australis	1	25	1	1	P
Juncus vaginatus	1	38	1	<1	P
Lachnagrostis filiformis	3	88	1	3	P
Lepilaena bilocularis	4	66	0	0	P
Limosella australis	3	84	2	<1	P
Myriophyllum verrucosum	3	22	2	<1	P
Persicaria prostrata	2	44	2	<1	P
Potamogeton ochreatus	3	28	3	<1	P
Puccinellia stricta	2	34	2	<1	P
Ranunculus diminutus	3	97	2	<1	P
Schoenoplectus pungens	2	25	2	<1	P

Threatened communities: EPBC Act 1999 – *Upland Wetlands of the New England Tablelands and the Monaro Plateau.*

Equivalent vegetation types: Represents a modification and extension of Community 4 [*Deep freshwater sedge-herb marsh*] of Benson & Jacobs (1994).

Frequently occurring weeds: Common weeds of this community include those that characterise other ephemeral wetland communities in the region, and include *Cirsium vulgare* (0.16), *Juncus articulatus* (0.41), *Juncus bufonius* (0.25) and *Rumex crispus* (0.47). *Hordeum marinum* (0.5), a species unique to saline environments was also recorded within this community.

Threats: This tableland wetland type generally occupies deeper, more permanent lakes than L12 and L3, so is less prone to draining, grazing and conversion to exotic pasture or cropping. However, Benson & Jacobs (1994) reported at least one example of a large Monaro lake drained by a channel cut through an adjacent hill. Some examples of this community are located within highly modified rural catchments, and may be subject to increased frequency of eutrophication and invasion by exotic plants at various stages of their wetting/drying cycles. Climate change impacts on this community will depend on its effects on the length and frequency of inundation of these wetlands.

Reservation status: No records of this community occur on conservation reserves.

Extent of clearing: The original extent of these herbaceous wetlands is likely to have been greatly reduced across their range by widespread draining, cropping and exotic pasture establishment.

Reference: Benson, J.S. & Jacobs, S.W.L. (1994) Plant communities of the Monaro lakes. *Cunninghamia* 3: 651–676.

Formation: Grassy Woodlands

Class: Subalpine Woodlands

a34: Weeping Snow Gum shrub-grass open woodland of the Australian Alps bioregion

Scientific Name: *Eucalyptus lacrimans / Hakea microcarpa – Pimelea linifolia* subsp. *caesia / Poa phillipsiana*

Number of samples:	6
Richness [mean (±SD)]:	25 (1)
Slope (degrees):	(1) 3–11 (16)
Altitude (m asl):	(1241) 1321–1351 (1416)
Ave. Annual Rainfall (mm):	(1012) 1089–1251 (1499)
Temp. Annual Range (°C):	(23.2) 23.7–24 (24.6)

Vegetation Description: Community a34 is mid-high open woodland with a very sparse canopy dominated by *Eucalyptus lacrimans* to a height of about 5 metres. The understorey ranges from grass-dominated (most commonly *Poa phillipsiana*) to shrub-dominated (mostly *Hakea microcarpa*). Several species that are uncommon on the treeless plains of Kosciuszko NP were recorded in this community including *Daviesia ulicifolia*, *Dichelachne rara*, *Grevillea lanigera*, *Lepidosperma curtisiae*, *Lomandra longifolia* var. *exilis*, *Phebalium squamulosum* subsp. *ozothamnoides* and *Tetratheca bauerifolia*.

This community occurs only in Kosciuszko NP on isolated knolls and low ridges of frost hollows between Long and Nungar Plains in Kosciuszko NP (including the Kiandra area and Currango Plain). It is especially prominent on the slopes of the Murrumbidgee River at Gulf Bend, below Tantangara Dam. This community is considered distinct from vegetation containing *Eucalyptus lacrimans* around Adaminaby, where the understorey is dominated by *Themeda australis* and contains many elements of the Monaro Plains grassland communities such as Community r6 [*Dry Tussock Grassland of the Monaro in the South Eastern Highlands bioregion*]. Further sampling is required to quantify the existence of this plant community.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acrothamnus hookeri	1	67	1	8	P
Asperula gunnii	1	67	1	5	P
Austrostipa nivicola	2	33	1	<1	P
Bossiaea foliosa	2	50	2	4	P
Carex breviculmis	1	83	1	13	P
Craspedia coolaminica	1	50	1	2	P
Craspedia jamesii	1	83	1	4	P
Dillwynia prostrata	3	33	3	<1	P
Eucalyptus lacrimans	2	83	3	<1	P
Geranium antrorsum	1	50	1	3	P
Hakea microcarpa	1	100	1	3	P
Hovea aff. *heterophylla* (Kiandra)	1	33	1	<1	P
Leptorhynchos squamatus	1	33	1	3	P
Linum marginale	1	33	1	1	P
Microseris lanceolata	1	67	1	7	P
Olearia myrsinoides	1	33	1	<1	P
Pimelea linifolia	1	100	1	8	P
Poa clivicola	2	50	3	2	P
Poa phillipsiana	2	83	3	3	P
Poranthera microphylla	1	83	1	27	P
Ranunculus graniticola	1	67	1	4	P
Rytidosperma spp.	1	50	1	7	P
Scleranthus biflorus	1	67	1	10	P

Plate a34: *Eucalyptus lacrimans* is a sparse dominant of Community a34, which is confined to Kosciuszko NP (this example at Long Plain). The understorey may be shrubby or grassy.

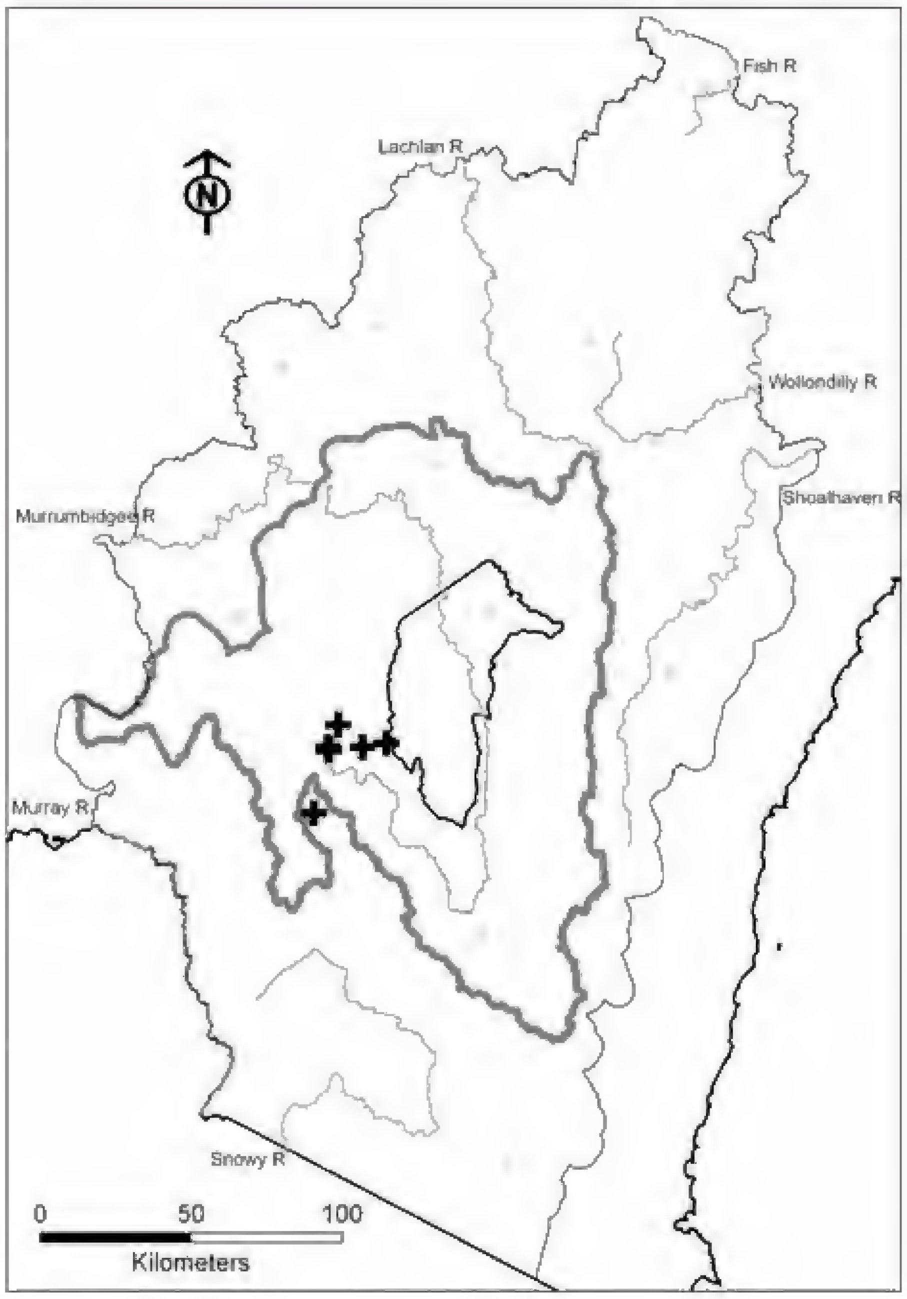

Fig. a34: Distribution of field samples assigned to this community.

Scleranthus fasciculatus	2	33	1	1	P
Senecio pinnatifolius var. *alpinus*	1	33	1	3	P
Trisetum spicatum	1	83	1	3	P
Elymus scaber	1	50	1	21	C
Stylidium graminifolium sens. lat	1	50	1	25	C

Threatened communities: Nil.

Equivalent vegetation types: Community 34 [*Eucalyptus lacrimans low open woodland*] (McDougall & Walsh 2007).

Frequently occurring weeds: The weeds *Acetosella vulgaris* (0.50), *Cerastium vulgare* (0.33) and *Hypochaeris radicata* (0.67) are the most frequently recorded from this community, indicating past grazing disturbance.

Threats: The majority of sites contain dead trees of *Eucalyptus lacrimans*, with little or no recruitment of this species. The reason for the decline of the over–storey warrants investigation, but may be attributed in some way to the recent extended drought. This community is also highly localized, making it vulnerable to stochastic disturbance events.

Reservation status: Entirely within Kosciuszko NP.

Extent of clearing: Unknown. Large areas of *Eucalyptus pauciflora* subsp. *pauciflora* were cleared in the vicinity of this community in the early 20th Century to increase the grazing capacity of the land. The sparse nature of *Eucalyptus lacrimans* stands may have saved it from that fate.

Reference: McDougall, K.L. & Walsh, N.G. (2007) Treeless vegetation of the Australian Alps. *Cunninghamia* 10: 1–57.

u22: Mountain Gum – Snow Gum ± Robertson's Peppermint grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions

Scientific Name: *Eucalyptus dalrympleana – Eucalyptus pauciflora* subsp. *pauciflora ± Eucalyptus radiata* subsp. *robertsonii / Acacia dealbata / Poa sieberiana – Stellaria pungens – Viola betonicifolia – Lomandra longifolia*

Number of samples:	224
Richness [mean (±SD)]:	39 (11)
Slope (degrees):	(0) 6–16 (35)
Altitude (m asl):	(462) 1109–1294 (1694)
Ave. Annual Rainfall (mm):	(701) 1075–1326 (1688)
Temp. Annual Range (°C):	(22.2) 23.7–24.7 (28.2)

Vegetation Description: Community u22 is a very tall grassy woodland to open forest dominated by *Eucalyptus dalrympleana* and *Eucalyptus pauciflora* subsp. *pauciflora*, occasionally with *Eucalyptus radiata* subsp. *robertsonii*. The shrub layer is generally sparse or absent with minor occurrences of *Acacia dealbata*, *Coprosma hirtella*, *Olearia erubescens* and *Platylobium montanum*. The understorey is characterised by a dense grassy / herbaceous cover, and is usually dominated by *Poa sieberiana,* infrequently with *Dichelachne sieberiana* or *Rytidosperma pallidum*. Common forbs include *Stellaria pungens*, *Viola betonicifolia*, *Lomandra longifolia*, *Acaena novae-zelandiae*, *Asperula scoparia*, *Glycine clandestina*, *Clematis aristida*, *Stylidium graminifolium sens. lat.*, *Poranthera microphylla*, *Coronidium scorpioides* and *Wahlenbergia stricta*.

This community is distributed from south of Batlow in the Bago-Maragle area, through northern Kosciuszko, Brindabella and Namadgi NPs, and extending eastwards to the Tinderry Ranges. It is found mainly on sandy-loam soils derived from granitoids. It grades into Community u239 [*Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open* *forest of the Australian Alps and South Eastern Highlands bioregions*] except in the Tinderry Ranges where it often grades into u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*]. In the Brindabella ranges, it may grade into Community u52 [*Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands and northern Australian Alps bioregions*] on sheltered slopes, and Community u27 [*Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion*] in frost hollows downslope.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	2	58	2	24	P
Acacia melanoxylon	1	24	1	13	P
Acacia pravissima	1	8	1	<1	P
Acaena echinata	1	20	1	8	P
Acaena novae-zelandiae	2	74	1	24	P
Acrothamnus hookeri	1	25	1	7	P
Acrotriche serrulata	1	23	1	10	P
Arthrochilus huntianus	1	2	1	<1	P
Arthropodium milleflorum	1	29	1	7	P
Arthropodium **Snowy R. catchment**	2	17	2	<1	P
Asperula scoparia	2	75	1	18	P
Brachyscome aculeata	1	9	1	2	P
Brachyscome spathulata	1	41	1	9	P
Bulbine bulbosa	1	13	1	4	P
Caladenia alpina	1	3	1	<1	P
Caladenia gracilis	1	4	1	1	P
Calotis scabiosifolia var. *integrifolia*	1	12	1	2	P
Carex breviculmis	2	26	1	12	P
Cassinia aculeata	2	37	1	12	P
Chiloglottis valida	2	16	1	2	P
Clematis aristata	1	72	1	20	P
Coprosma hirtella	1	52	1	9	P
Coronidium scorpioides	1	55	1	17	P
Craspedia spp.	2	16	1	3	P
Craspedia variabilis	1	39	1	3	P
Cullen tenax	2	4	1	<1	P
Cymbonotus preissianus	1	24	1	5	P
Cynoglossum australe	1	10	1	3	P
Daviesia latifolia	2	33	2	5	P
Daviesia mimosoides subsp. *mimosoides*	3	23	2	8	P
Daviesia ulicifolia	2	31	1	9	P
Deyeuxia monticola	2	22	1	4	P
Deyeuxia quadriseta	1	11	1	4	P
Deyeuxia rodwayi	1	7	2	<1	P
Dianella tasmanica	1	32	2	15	P
Dichelachne hirtella	1	4	1	1	P
Dichelachne inaequiglumis	2	22	2	5	P
Dichelachne sieberiana	2	24	2	4	P
Dipodium roseum	1	3	1	<1	P
Dipodium spp.	1	1	1	<1	P
Elymus scaber	2	33	1	20	P
Epacris breviflora	1	7	2	2	P
Epilobium billardierianum subsp. *cinereum*	1	19	1	4	P
Eucalyptus dalrympleana	3	86	2	15	P
Eucalyptus pauciflora subsp. *pauciflora*	3	82	3	17	P
Eucalyptus radiata subsp. *robertsonii*	3	36	3	7	P
Euchiton japonicus	1	31	1	14	P
Euphrasia collina subsp. *paludosa*	1	9	1	2	P
Euphrasia collina subsp. *speciosa*	1	2	1	<1	P
Exocarpos strictus	1	29	1	11	P
Festuca asperula	1	11	1	<1	P

Plate u22: An example of Community u22 containing *Eucalyptus pauciflora* subsp. *pauciflora* with a grassy understorey dominated by *Poa sieberiana*. Plot UMCPG06, north of Brayshaw's Hut, eastern boundary of Kosciuszko NP.

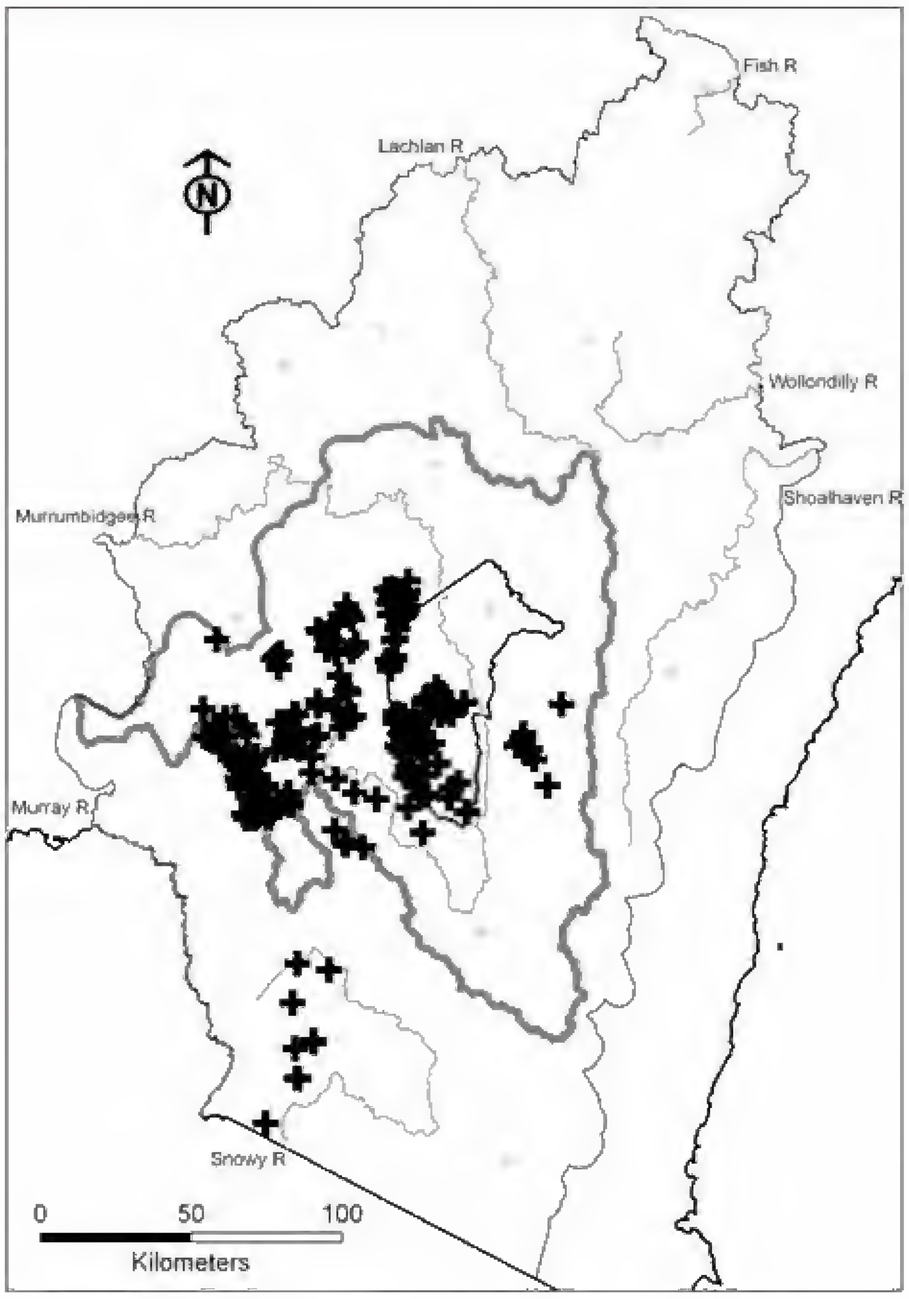

Fig. u22: Distribution of field samples assigned to this community.

Galium ciliare	2	5	2	<1	P
Galium polyanthum	1	5	1	2	P
Gastrodia sesamoides	1	3	1	<1	P
Gentianella sylvicola	1	4	1	<1	P
Geranium potentilloides	1	40	1	11	P
Geranium solanderi	1	33	1	18	P
Glycine clandestina	1	75	1	26	P
Gonocarpus tetragynus	2	48	2	48	C
Hookerochloa eriopoda	1	13	2	1	P
Hovea asperifolia	4	1	0	0	P
Lachnagrostis aemula	1	6	1	<1	P
Lagenophora stipitata	1	43	1	15	P
Leptinella filicula	1	14	1	2	P
Leucopogon gelidus	1	6	1	2	P
Lobelia gibbosa	1	4	1	<1	P
Lobelia pedunculata	1	25	1	3	P
Lomandra filiformis subsp. *filiformis*	1	33	1	15	P
Lomandra longifolia	2	78	2	40	P
Lomatia myricoides	1	25	1	11	P
Lotus australis	1	2	1	<1	P
Luzula flaccida	1	42	1	11	P
Microseris lanceolata	1	15	1	6	P
Myosotis australis	1	2	1	<1	P
Olearia erubescens	1	52	1	9	P
Olearia megalophylla	1	16	1	4	P
Oreomyrrhis eriopoda	1	42	1	11	P
Ozothamnus thyrsoideus	1	6	1	2	P
Persoonia chamaepeuce	1	41	1	9	P
Persoonia subvelutina	1	5	1	1	P
Picris angustifolia	2	10	1	1	P
Platylobium montanum	2	43	2	8	P
Poa induta	3	17	2	5	P
Poa sieberiana	3	88	2	45	P
Poa tenera	2	8	2	2	P
Podolepis hieracioides	1	5	1	<1	P
Polyscias sambucifolia	1	20	2	4	P
Poranthera microphylla	1	57	1	25	P
Pterostylis coccina	1	6	1	<1	P
Pterostylis decurva	1	8	1	<1	P
Pterostylis fischii	1	1	1	<1	P
Pterostylis monticola	1	12	1	<1	P
Pultenaea juniperina	2	4	3	<1	P
Ranunculus lappaceus	1	46	1	8	P
Ranunculus plebeius	1	10	1	3	P
Ranunculus scapiger	1	4	1	1	P
Rytidosperma pilosum	1	19	2	8	P
Senecio biserratus	1	3	1	<1	P
Senecio diaschides	1	21	1	4	P
Senecio gunnii	1	25	1	8	P
Senecio linearifolius	1	10	1	5	P
Senecio prenanthoides	2	38	1	18	P
Stackhousia monogyna	1	33	1	11	P
Stellaria pungens	2	88	2	27	P
Stylidium graminifolium sens. lat.	1	63	1	23	P
Tasmannia lanceolata	1	9	1	3	P
Tetratheca bauerifolia	1	17	1	6	P
Tetratheca ciliata	2	10	1	<1	P
Thysanotus tuberosus	1	11	1	3	P
Veronica calycina	1	49	1	14	P
Veronica derwentiana	1	35	1	5	P
Veronica perfoliata	1	8	1	4	P
Viola betonicifolia	2	85	1	23	P
Wahlenbergia gloriosa	1	8	1	2	P
Wahlenbergia stricta	1	54	1	16	P

Threatened communities: Parts of this community may contain TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: This community has affinities with VG97 [*Montane Acacia Dry/ Shrub/Herb/Grass Forest*] and VG100 [*ACT Montane Dry Shrub/Grass Forest*] (Gellie 2005).

Frequently occurring weeds: Weed species were not common within this community, with only *Hypochaeris radicata* (0.66) present in the majority of sites.

Threats: Community u22 is well reserved across its range. Extensive areas also occur within the State Forest estate, where selective logging has had some impact upon the overstorey. The impact of logging is an ongoing, albeit minor threat to the floristic integrity of this community. Inappropriate fire regimes represent a greater potential threat through its capacity to alter community floristics and structure over time.

Reservation status: The majority of examples of this community are found in Kosciuszko NP and Namadgi NR, and it is also known from Bimberi NR, Brindabella NP, Burnt School NR, Scabby Range NR, Tinderry NR, Yanununbeyan NP and Yaouk NR.

Extent of clearing: Likely to be minimal. Patches closer to the valley floor are more likely to have been cleared on freehold land.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u23: Snow Gum – *Epacris breviflora – Leptospermum myrtifolium* tall woodland to open forest of drainage depressions primarily of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus pauciflora* subsp. *pauciflora – Eucalyptus dalrympleana – Eucalyptus stellulata / Epacris breviflora – Leptospermum myrtifolium – Baeckea utilis / Acaena novae–zelandiae – Stylidium graminifolium sens. lat. – Poa sieberiana – Coronidium scorpioides*

Number of samples:	17
Richness [mean (±SD)]:	44 (12)
Slope (degrees):	(1) 2–8 (17)
Altitude (m asl):	(577) 1100–1230 (1375)
Ave. Annual Rainfall (mm):	(742) 876–1235 (1423)
Temp. Annual Range (°C):	(23.8) 24–25.2 (27.8)

Vegetation Description: Community u23 is a swampy tall eucalypt woodland to open forest dominated by *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus dalrympleana* and *Eucalyptus stellulata*. The well developed shrub layer is dominated by *Epacris breviflora*, *Leptospermum myrtifolium*, *Baeckea utilis*, *Hakea microcarpa* and *Olearia erubescens*. Low shrubs include *Persoonia chamaepeuce*, *Acrothamnus hookeri*, *Acrotriche serrulata* and *Grevillea lanigera*. The diverse groundlayer is typical of subalpine woodland communities and includes *Poa sieberiana*, *Elymus scaber*, *Hookerochloa eriopoda*, *Poa helmsii*, *Acaena novae-zelandiae*, *Stylidium graminifolium sens. lat.*, *Coronidium scorpioides*, *Asperula scoparia*, *Viola betonicifolia*, *Carex appressa*, *Hydrocotyle sibthorpioides*, *Hypericum japonicum*, *Ranunculus lappaceus*, *Lomandra longifolia*, *Poranthera microphylla*, *Stellaria pungens* and *Arthropodium milleflorum*.

This is a widespread community within the study area, extending from Tallaganda NP in the east to Maragle SF in the west. The majority of plot locations occur within the central part of its range, especially in Tinderry NR, Namadgi NP and Kosciuszko NP. It is confined to sheltered locations in montane environments, generally adjacent to, or within drainage depressions. Although it is most common on granite, it also occurs on basalt and metasediments. A number of widespread montane communities occur in association with this community, including Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern*

Highlands bioregions], Community u27 [*Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion*], Community u239 [*Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions*] and Community u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acaena novae-zelandiae	2	100	1	27	P
Arthropodium milleflorum	1	41	1	8	P
Asperula gunnii	2	24	1	5	P
Asperula scoparia	2	59	2	22	P
Baeckea utilis	3	65	2	1	P
Baloskion australe	2	24	1	2	P
Blechnum penna-marina subsp. *alpina*	2	24	2	1	P
Bossiaea foliosa	3	24	2	4	P
Brachyscome spathulata	1	41	1	11	P
Bulbine bulbosa	2	24	1	4	P
Carex appressa	2	53	1	7	P
Chiloglottis valida	1	24	1	2	P
Coronidium scorpioides	2	71	1	20	P
Deyeuxia quadriseta	1	24	1	4	P
Empodisma minus	2	29	2	3	P
Epacris breviflora	2	94	1	2	P
Eucalyptus dalrympleana	2	76	3	20	P
Eucalyptus pauciflora subsp. *pauciflora*	3	82	3	21	P
Eucalyptus stellulata	2	53	2	3	P
Gonocarpus micranthus	2	41	1	2	P
Grevillea lanigera	2	29	1	3	P
Hakea microcarpa	2	41	1	3	P
Haloragis heterophylla	3	24	1	2	P
Hookerochloa eriopoda	3	35	2	2	P
Hydrocotyle sibthorpioides	2	53	2	4	P
Hypericum japonicum	2	53	1	3	P
Juncus australis	2	24	1	2	P
Leptospermum grandifolium	3	24	3	2	P
Leptospermum lanigerum	4	24	2	<1	P
Leptospermum myrtifolium	2	88	1	3	P
Olearia erubescens	1	41	1	12	P
Olearia megalophylla	1	24	1	5	P
Oxylobium ellipticum	4	24	1	4	P
Poa helmsii	2	35	2	3	P
Poa labillardierei	3	35	2	10	P
Ranunculus lappaceus	2	53	1	11	P
Rytidosperma penicillatum	2	24	1	3	P
Schoenus apogon	2	29	1	5	P
Stylidium graminifolium sens. lat.	2	88	1	25	P
Veronica subtilis	2	24	1	<1	P
Elymus scaber	2	41	1	21	C
Euchiton japonicus	2	41	1	15	C
Gonocarpus tetragynus	2	41	2	48	C
Lomandra longifolia	1	47	2	42	C
Poa sieberiana	2	71	2	48	C
Poranthera microphylla	2	47	1	27	C
Stellaria pungens	2	47	2	31	C
Viola betonicifolia	1	59	1	27	C

Threatened communities: Parts of this community may contain TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: Most similar to VG124 [*Western Montane/Sub-alpine Wet Heath/Herb Grass Woodland*] and VG146 [*Tableland Dry Herb/Grass Woodland*] (Gellie 2005).

Plate u23: Community u23 in headwaters of Little Glory Hole Creek beside Yarrangobilly Caves exit road, Kosciuszko NP, showing regenerating *Eucalyptus pauciflora* and a grass-shrub understorey.

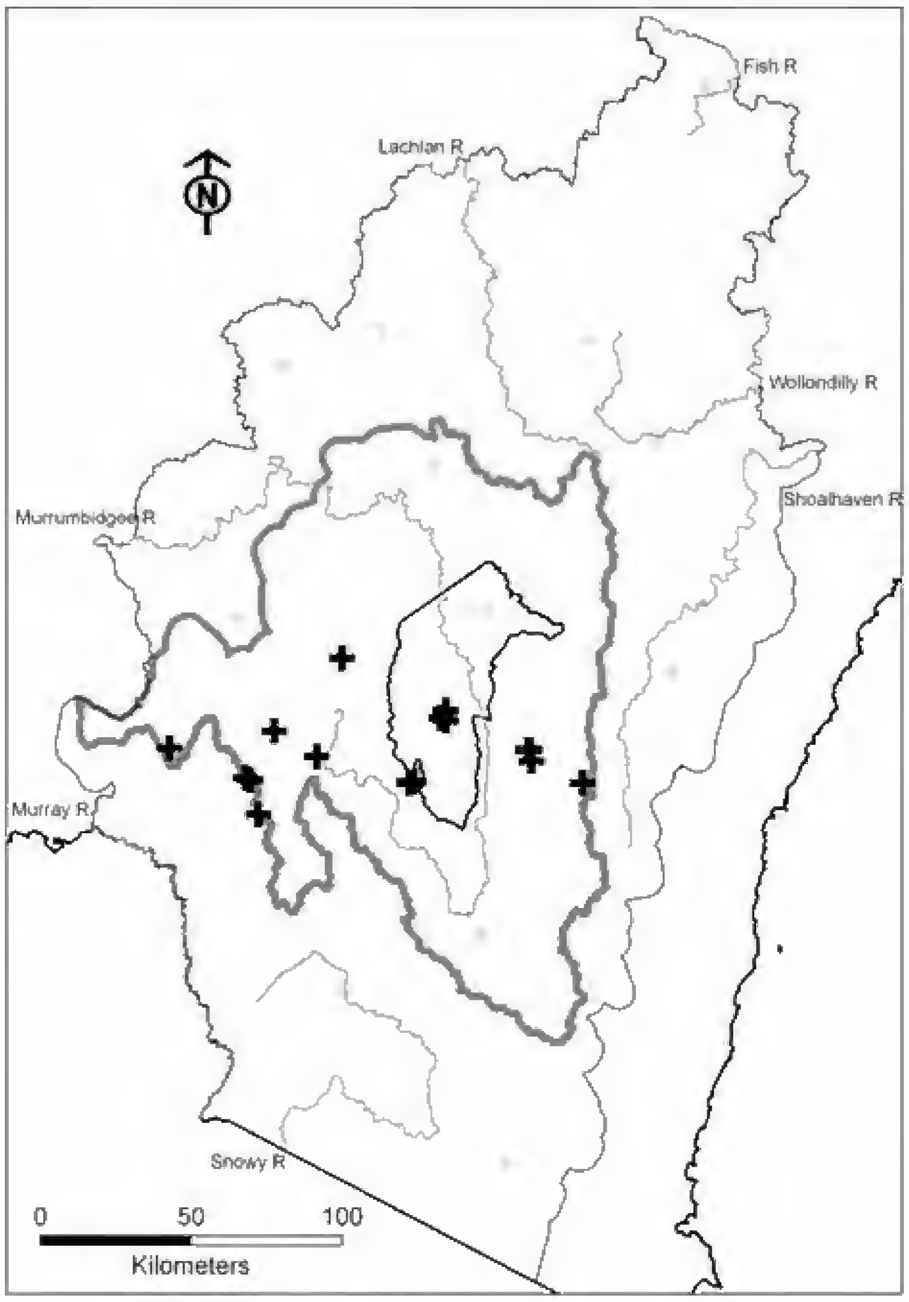

Fig. u23: Distribution of field samples assigned to this community.

Frequently occurring weeds: The weeds of this community are typical of other grassy woodlands in the South Eastern Highlands, suggesting past and possibly ongoing disturbance by grazing. This community also occurs in riparian environments, which are often subject to colonisation by weeds. The most common weeds recorded from this community include *Acetosella vulgaris* (0.23), *Centaurium erythraea* (0.23), *Cerastium vulgare* (0.31), *Crepis capillaris* (0.31), *Holcus lanatus* (0.54), *Hypochaeris radicata* (0.77), *Mimulus moschatus* (0.31), *Prunella vulgaris* (0.69), *Rosa rubiginosa* (0.23), *Trifolium dubium* (0.23) and *Trifolium repens* (0.46).

Threats: Although much of this community occurs on public land, it is not immune from disturbance or degradation. In many examples, weed invasion threatens ground and shrub layer structure and composition. Grazing by feral, and in some areas, native herbivores may exacerbate this problem. Because the community generally occurs within extensively forested regions, it is also at risk from frequent and intense fire, which may influence floristic and structural composition over time.

Reservation status: Likely to be well reserved, and is known to occur in Kosciuszko NP, Namadgi NP, Scabby Range NR, Tallaganda NP and Tinderry NR.

Extent of clearing: Negligible.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Plate u27: Community u27 with *Eucalyptus rubida*, *Eucalyptus pauciflora* and *Poa* spp. dominated grassy groundlayer near Mt Clear Camp ground track southern Naas Valley, ACT.

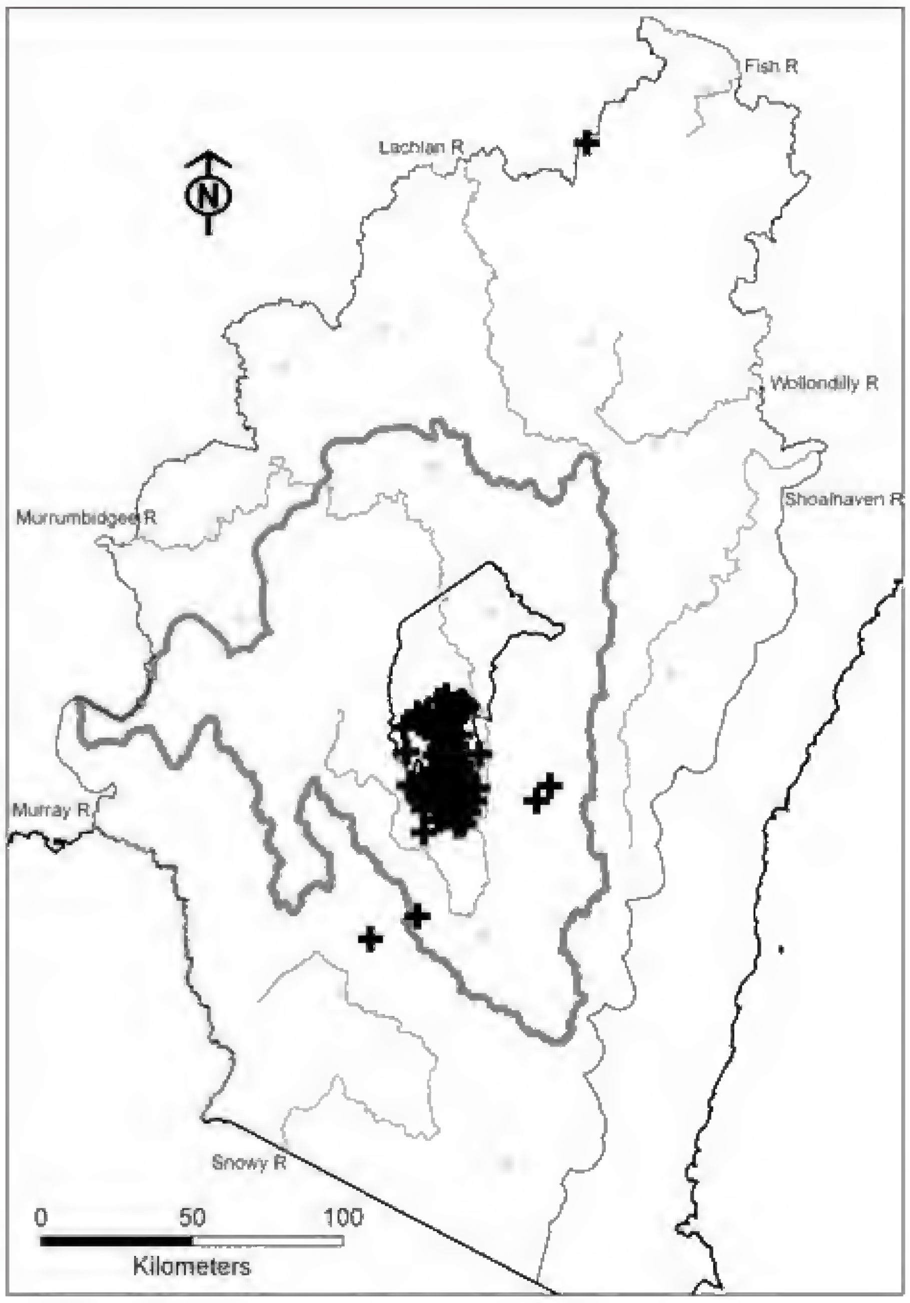

Fig. u27: Distribution of field samples assigned to this community.

u27: Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus pauciflora* subsp. *pauciflora – Eucalyptus rubida* ± *Eucalyptus dives / Acacia dealbata / Poa induta – Poa sieberiana – Glycine clandestina – Gonocarpus tetragynus*

Number of samples:	102
Richness [mean (±SD)]:	42 (8)
Slope (degrees):	(1) 7–20 (34)
Altitude (m asl):	(890) 1088–1331 (1558)
Ave. Annual Rainfall (mm):	(656) 783–988 (1253)
Temp. Annual Range (°C):	(22.7) 24.3–25.7 (26.7)

Vegetation Description: Community u27 us a tall grassy woodland to open forest dominated by *Eucalyptus pauciflora* subsp. *pauciflora* often with *Eucalyptus rubida*, and occasionally with *Eucalyptus dives* or *Eucalyptus viminalis*. The shrub layer is generally sparse or absent with *Acacia dealbata* and *Cassinia longifolia* being the only frequently occurring shrub species, along with occasional occurrences of small shrubs such as *Acrotriche serrulata* and *Hibbertia obtusifolia*. *Daviesia ulicifolia* may be present in sites which have been burnt in the last 20 – 30 years. The understorey is characterised by dense grassy / herbaceous cover, and is dominated by grasses such as *Poa induta*, *Poa sieberiana*, *Elymus scaber*, *Dichelachne rara* and *Themeda australis*. Forbs include *Glycine clandestina*, *Gonocarpus tetragynus*, *Lomandra longifolia*, *Asperula scoparia*, *Viola betonicifolia*, *Stellaria pungens*, *Senecio gunnii*, *Euchiton sphaericus*, *Luzula* spp. and *Acaena novae-zelandiae*.

Plot records indicate that Community u27 is distributed mostly on mid to lower slopes on ranges and frost hollow depressions in the Namadgi region and adjacent granitic ranges. However, it is poorly sampled throughout its range and is considered to occur in the Monaro between Bredbo, Bombala and Berridale. In the Namadgi region, it generally occurs in valley floors and lower slopes associated with dry montane forests including Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*], Community u29 [*Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of* *the South Eastern Highlands bioregion*] and Community u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*].

This community is primarily characterised by plots sampled in the ACT. Further sampling of such vegetation in NSW will be useful to better define character species across its range.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia dealbata	2	67	2	25	P
Acaena novae-zelandiae	1	63	1	27	P
Acaena ovina	1	49	1	7	P
Acrothamnus hookeri	1	23	1	7	P
Acrotriche serrulata	1	44	1	10	P
Ajuga australis	1	33	1	7	P
Arthropodium milleflorum	1	28	1	8	P
Asperula scoparia	2	69	2	21	P
Asplenium flabellifolium	1	21	1	8	P
Bossiaea buxifolia	1	21	1	7	P
Brachyscome aculeata	1	14	1	2	P
Brachyscome rigidula	1	11	1	2	P
Brachyscome spathulata	1	32	1	10	P
Bursaria spinosa	1	25	1	10	P
Calotis scabiosifolia var. *integrifolia*	1	29	1	2	P
Carex inversa	1	46	1	7	P
Cassinia longifolia	2	60	1	15	P
Cassinia quinquefaria	2	4	1	<1	P
Chrysocephalum semipapposum	1	13	1	4	P
Craspedia spp.	1	18	1	3	P
Craspedia variabilis	1	15	1	5	P
Cullen microcephalum	1	25	1	2	P
Cymbonotus preissianus	1	15	1	6	P
Cymbonotus spp.	1	32	1	2	P
Cynoglossum australe	1	25	1	3	P
Cynoglossum suaveolens	1	11	1	3	P
Daviesia mimosoides subsp. *mimosoides*	1	31	2	9	P
Daviesia ulicifolia	1	26	2	10	P
Deyeuxia monticola	1	25	1	5	P
Dichelachne micrantha	1	28	1	9	P
Dichelachne rara	2	59	1	7	P
Dichondra repens	1	36	2	20	P
Echinopogon cheelii	1	15	1	<1	P
Elymus scaber	2	63	1	20	P
Epilobium billardierianum subsp. *billardierianum*	1	33	1	<1	P
Eucalyptus dives	3	36	3	18	P
Eucalyptus pauciflora subsp. *pauciflora*	3	80	3	19	P
Eucalyptus rubida	3	61	3	7	P
Eucalyptus stellulata	3	13	2	3	P
Eucalyptus viminalis	3	29	3	12	P
Euchiton sphaericus	1	64	1	5	P
Exocarpos strictus	1	29	1	12	P
Galium gaudichaudii	1	33	1	9	P
Galium polyanthum	1	11	1	2	P
Geranium obtusisepalum	1	5	2	<1	P
Geranium potentilloides	2	30	1	13	P
Geranium solanderi	2	42	1	19	P
Glycine clandestina	2	82	1	28	P
Gonocarpus tetragynus	2	82	2	47	P
Goodenia pinnatifida	1	4	1	<1	P
Hibbertia obtusifolia	2	45	1	34	C
Hovea linearis	1	34	1	13	P
Hypericum gramineum	1	50	1	25	P
Indigofera australis	1	20	1	7	P
Leucopogon fletcheri subsp. *brevisepalus*	1	12	1	3	P
Linum marginale	1	6	1	1	P
Lomandra filiformis subsp. *filiformis*	1	36	1	15	P
Lomandra longifolia	2	75	2	41	P
Lotus australis	1	4	1	<1	P
Luzula spp.	1	63	1	4	P
Mirbelia oxylobioides	1	12	1	3	P
Olearia erubescens	1	25	1	12	P
Oreomyrrhis eriopoda	1	55	1	12	P
Oxylobium ellipticum	1	13	2	4	P
Ozothamnus stirlingii	1	6	1	<1	P
Persoonia chamaepeuce	1	23	1	11	P
Pimelea linifolia	1	31	1	8	P
Pimelea treyvaudii	2	10	1	<1	P
Plantago varia	1	57	1	10	P
Poa induta	3	80	2	3	P
Poa sieberiana	3	78	2	47	P
Pultenaea procumbens	1	19	1	4	P
Ranunculus lappaceus	1	23	1	10	P
Rytidosperma penicillatum	1	33	1	3	P
Schoenus apogon	1	15	1	5	P
Scleranthus biflorus	1	36	1	9	P
Scleranthus diander	1	20	1	1	P
Senecio gunnii	1	63	1	7	P
Senecio quadridentatus	2	21	1	5	P
Solenogyne gunnii	1	14	1	5	P
Stackhousia monogyna	1	51	1	11	P
Stellaria pungens	3	59	2	30	P
Stylidium graminifolium sens. lat.	1	50	1	25	P
Themeda australis	1	56	2	20	P
Veronica calycina	1	47	1	15	P
Veronica derwentiana	1	26	1	6	P
Viola betonicifolia	1	75	1	26	P
Wahlenbergia gloriosa	1	8	1	2	P
Wahlenbergia graniticola	1	9	2	<1	P
Wahlenbergia stricta	1	59	1	17	P

Threatened communities: TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: No equivalent communities, defined by plots not used in previous classifications. May have affinities with VG100 [*ACT Montane Dry Shrub/Grass Forest*] from Gellie (2005)

Frequently occurring weeds: Common weeds of the pastoral districts of the South Eastern Highlands are a feature in this community, namely *Acetosella vulgaris* (0.23), *Centaurium erythraea* (0.51), *Cirsium vulgare* (0.25), *Crepis capillaris* (0.27) and *Hypochaeris radicata* (0.67).

Threats: Widespread historic clearing of this community has resulted in it becoming severely fragmented. This in turn has resulted in a disruption to essential ecological processes and has facilitated secondary disturbances such as over-grazing, weed invasion and the incursion of feral animals. Within existing remnants, weed invasion represents a major threat to ground and shrub layer species, especially where the community occurs on freehold land subject to grazing by domestic stock, Grazing by feral, and in some areas, native herbivores has a similar effect. Where the community occurs within extensively forested areas, frequent and intense fire may affect its structural and floristic composition. Within farming districts, canopy dieback is widespread.

Reservation status: Although this community was only sampled within in the ACT Reserve system, it is distributed across large parts of the South Eastern Highlands bioregion. Many examples of this community are found in Namadgi NP but it is also known from Burnt School NR, Kosciuszko NP, Scabby Range NR, Strike-a-Light NR and Yaouk NR.

Extent of clearing: Likely to be variable, with clearing rates of this community in valley floors being considerably higher than upslope.

u28: Snow Gum – Mountain Gum – *Daviesia mimosoides* tall dry grass-shrub subalpine open forest of the Australian Alps and South Eastern Highlands bioregions

Plate u28: Community u28 at Smokers trail in Namadgi NP with *Eucalyptus dalrympleana* and *Eucalyptus pauciflora* and shrubs including *Daviesia mimosoides* and *Coprosma hirtella*.

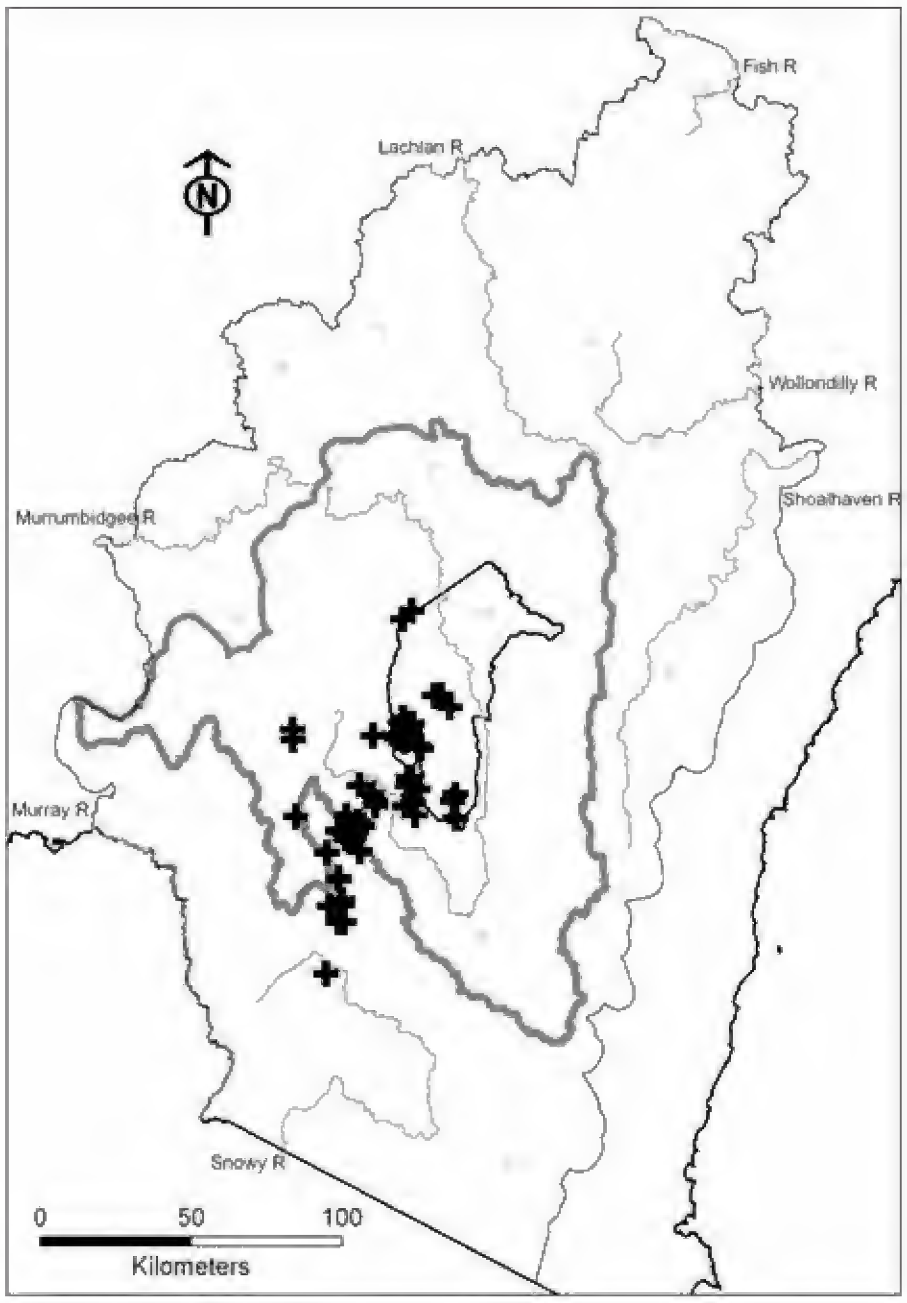

Fig. u28: Distribution of field samples assigned to this community.

Scientific Name: *Eucalyptus pauciflora subsp. pauciflora – Eucalyptus dalrympleana ± Eucalyptus rubida / Daviesia mimosoides subsp. mimosoides – Persoonia chamaepeuce / Poa sieberiana – Stellaria pungens – Lomandra longifolia*

Number of samples:	54
Richness [mean (±SD)]:	24 (7)
Slope (degrees):	(0) 6–17 (42)
Altitude (m asl):	(978) 1181–1391 (1582)
Ave. Annual Rainfall (mm):	(737) 965–1129 (1587)
Temp. Annual Range (°C):	(22.3) 23.7–24.8 (25.7)

Vegetation Description: Community u28 is a tall eucalypt woodland to open forest dominated by *Eucalyptus pauciflora* subsp. *pauciflora* and *Eucalyptus dalrympleana*. The shrubby midstorey is dominated by *Daviesia mimosoides* subsp. *mimosoides*, *Pimelea linifolia*, *Daviesia ulicifolia*, *Veronica perfoliata*, *Olearia erubescens* and *Exocarpos strictus*. Low shrubs include *Persoonia chamaepeuce*, *Hibbertia obtusifolia* and *Tetratheca bauerifolia*. The diverse groundlayer shares affinities with other subalpine woodlands and includes *Poa sieberiana*, *Stellaria pungens*, *Lomandra longifolia*, *Goodenia hederacea* subsp. *hederacea*, *Stylidium graminifolium sens. lat.*, *Poranthera microphylla*, *Viola betonicifolia*, *Senecio gunnii*, *Gonocarpus tetragynus* and *Asperula scoparia*.

This community is largely restricted to Namadgi NR, Kosciuszko NP and Scabby Range NR within the Australian Alps bioregion. Smaller occurrences also occur in adjacent parts of the South Eastern Highlands bioregion. It is generally confined to sheltered locations on metasedimentary and granite geologies. Communities with which Community u28 is associated are those characteristic of similar environments, including Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*], Community u27 [*Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies of the South Eastern Highlands bioregion*], Community u239 [*Alpine Ash – Mountain Gum ± Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands bioregions*] and Community u150 [*Broad-leaved Peppermint – Mountain Gum tall grass-forb open forest of the South Eastern Highlands and Australian Alps bioregions*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia obliquinervia	2	17	2	3	P
Bossiaea foliosa	2	20	2	4	P
Brachyscome spathulata	1	26	1	11	P
Caladenia gracilis	1	17	1	1	P
Daviesia mimosoides subsp. *mimosoides*	2	67	2	8	P
Daviesia ulicifolia	2	48	2	9	P
Deyeuxia monticola	1	19	1	5	P
Eucalyptus dalrympleana	3	65	3	19	P
Eucalyptus pauciflora subsp. *pauciflora*	3	94	3	20	P
Eucalyptus rubida	2	31	3	8	P
Exocarpos strictus	2	31	1	12	P
Goodenia hederacea subsp. *hederacea*	1	67	2	16	P
Grevillea lanigera	2	17	1	3	P
Leucopogon fletcheri subsp. *brevisepalus*	1	24	1	3	P
Lomandra longifolia	1	74	2	42	P

Plate u118: Community u118 with *Eucalyptus stellulata* and a diverse grass/forb groundcover, near Spicers Creek firetrail east of Yarrangobilly, Kosciuszko NP (near plot UMCPG09).

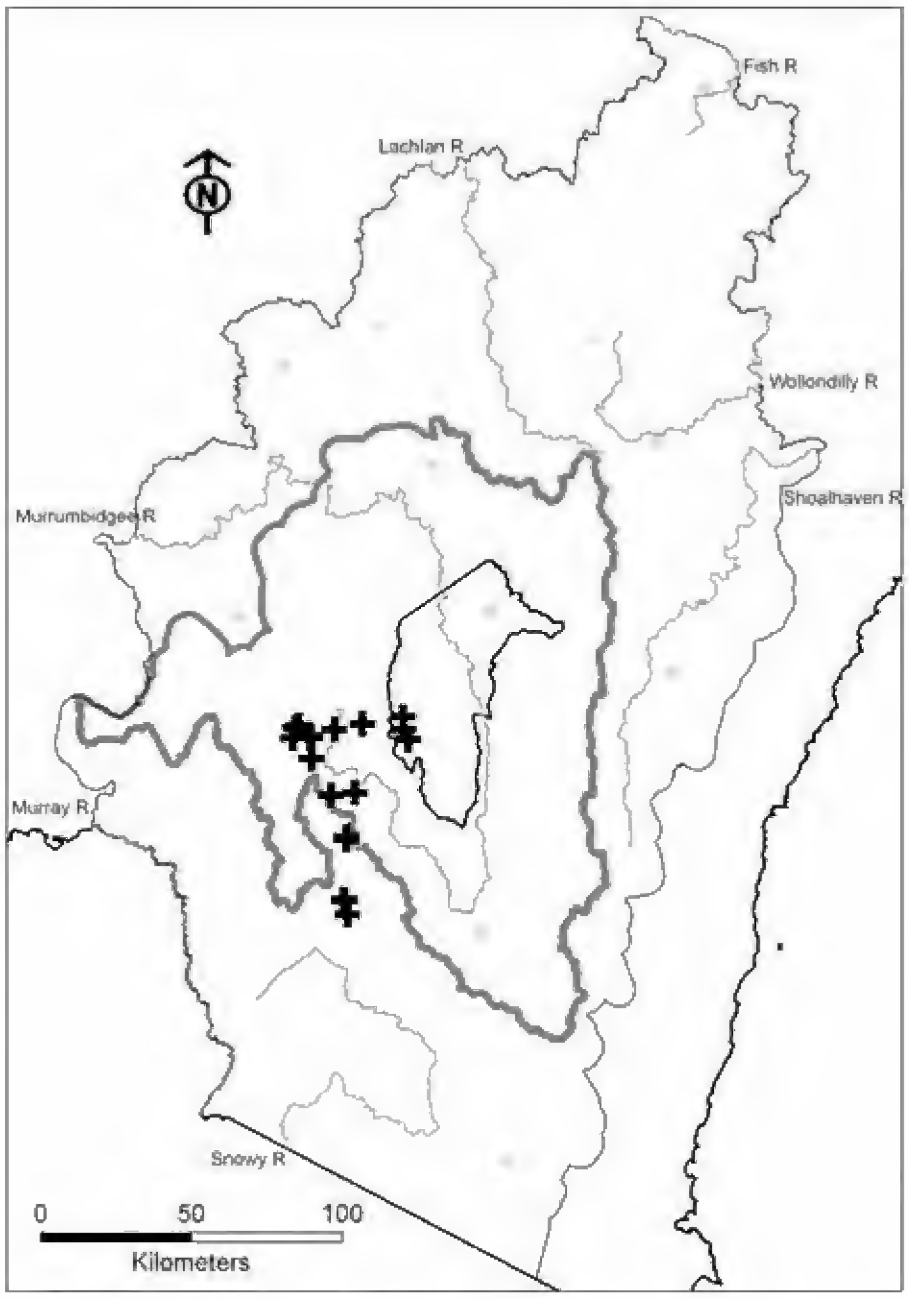

Fig. u118: Distribution of field samples assigned to this community.

Lomatia myricoides	1	28	1	11	P
Olearia erubescens	1	33	1	12	P
Oxylobium ellipticum	1	26	1	4	P
Ozothamnus thyrsoideus	1	30	1	2	P
Persoonia chamaepeuce	1	67	1	10	P
Pimelea linifolia	1	50	1	8	P
Poa sieberiana	2	93	2	47	P
Podolobium alpestre	2	20	2	2	P
Poranthera microphylla	1	48	1	27	P
Senecio gunnii	1	33	1	9	P
Stellaria pungens	1	76	2	31	P
Stylidium graminifolium sens. lat	1	54	1	25	P
Tetratheca bauerifolia	1	35	1	7	P
Veronica perfoliata	1	33	1	4	P
Hibbertia obtusifolia	1	54	1	34	C
Viola betonicifolia	1	41	1	27	C

Threatened communities: Grassy examples of this community at lower altitudes may be the TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: Mostly defined by new plots, but may have some similarity to VG98 [*Western Montane Moist Shrub Forest*] (Gellie 2005).

Frequently occurring weeds: *Hypochaeris radicata* (0.27) is the most commonly recorded weed in this community, which probably reflects both minor past disturbance, and the colonising capacity of that species.

Threats: Although this community is largely confined to public land, the impacts of grazing by feral herbivores and inappropriate fire regimes have the potential to alter its condition.

Reservation status: This community is likely to be well reserved, with examples occurring in Brindabella SCA, Kosciuszko NP, Namadgi NP, Scabby Range NR and Yaouk NR.

Extent of clearing: Considered to be minor.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u118: Black Sallee grass-herb woodland in drainage depressions and moist valley flats in the South Eastern Highlands and Australian Alps bioregions

Scientific Name: *Eucalyptus stellulata / Rubus parvifolius – Pimelea pauciflora / Stellaria pungens – Acaena ovina – Asperula scoparia – Acaena novae–zelandiae – Dichondra repens – Poranthera microphylla*

Number of samples:	20
Richness [mean (±SD)]:	34 (7)
Slope (degrees):	(0) 3–10 (32)
Altitude (m asl):	(972) 1026–1172 (1400)
Ave. Annual Rainfall (mm):	(749) 982–1227 (1340)
Temp. Annual Range (°C):	(23.5) 25.1–25.7 (26.1)

Vegetation Description: Community u118 is a eucalypt woodland characterised by a tall canopy of *Eucalyptus stellulata*, with occasional occurrences of *Eucalyptus pauciflora* subsp. *pauciflora* and/or *Eucalyptus rubida*. A layer of low to medium shrubs may be present, as scattered individuals to dense patches, commonly including *Pimelea pauciflora*, *Epacris breviflora*, *Hakea microcarpa*, *Acacia siculiformis* and *Grevillea lanigera*. The groundlayer is generally dense to continuous, with a diverse layer of forbs and low shrubs commonly including *Acaena novae-zelandiae*, *Acaena ovina*, *Acrothamnus hookeri*, *Dichondra repens*, *Geranium solanderi*, *Poranthera microphylla*, *Rubus parvifolius*, *Stellaria pungens*, *Themeda australis*, *Viola betonicifolia* covering the ground between tall tussocks of grasses such as *Poa sieberiana*, *Poa labillardierei*, *Poa phillipsiana*, *Poa helmsii* and sedges including *Carex appressa.*

Community u118 is recorded from moist footslopes of drainage depressions and margins of broad cold-air drainage flats on sandy soils, from the Upper Cotter area in the ACT, west to Yarrangobilly, south to Providence Portal, Eucumbene and Nimmo. It is also known to occur in areas east to Captains Flat and west into the Upper Slopes subregion of the South Western Slopes bioregion. This community is considered under-sampled across its geographic range.

In similar habitats at lower altitudes to the east of its range, this community may be replaced by Community r2 [*Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion*], while in swampier sites it may grade into Community u23 [*Snow Gum – Epacris breviflora – Leptospermum myrtifolium tall woodland to open forest of drainage depressions primarily of the South Eastern Highlands bioregion]* with a greater component of moisture-loving shrubs, sedges and grasses.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia siculiformis	2	33	1	<1	P
Acaena novae-zelandiae	1	67	1	27	P
Acaena ovina	1	76	1	7	P
Acrothamnus hookeri	1	57	1	7	P
Asperula scoparia	1	67	2	22	P
Bulbine bulbosa	2	29	1	4	P
Carex appressa	1	48	1	7	P
Carex inversa	1	29	1	8	P
Cullen microcephalum	1	24	1	2	P
Cymbonotus preissianus	1	38	1	6	P
Dichelachne micrantha	1	33	1	10	P
Dichondra repens	1	62	2	20	P
Epacris breviflora	1	33	1	2	P
Epilobium billardierianum subsp. *cinereum*	2	29	1	5	P
Eucalyptus rubida	1	38	3	9	P
Eucalyptus stellulata	3	100	2	3	P
Geranium antrorsum	1	33	1	3	P
Geranium solanderi	1	48	1	19	P
Geum urbanum	1	24	1	<1	P
Grevillea lanigera	2	33	1	3	P
Hakea microcarpa	1	38	1	3	P
Luzula densiflora	1	24	1	6	P
Mirbelia oxylobioides	1	24	1	3	P
Oxylobium ellipticum	2	24	1	4	P
Pimelea pauciflora	1	57	1	<1	P
Poa helmsii	3	29	2	3	P
Poa labillardierei	1	33	2	10	P
Poa phillipsiana	3	24	2	3	P
Poranthera microphylla	1	62	1	27	P
Ranunculus lappaceus	1	33	1	11	P
Rubus parvifolius	1	62	1	11	P
Scleranthus fasciculatus	2	29	1	1	P
Senecio gunnii	1	33	1	9	P
Solenogyne gunnii	1	33	1	5	P
Stellaria pungens	1	90	2	31	P
Veronica gracilis	1	24	1	1	P
Poa sieberiana	2	57	2	48	C
Themeda australis	2	48	2	21	C
Viola betonicifolia	1	48	1	27	C

Threatened communities: TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: VCA 303 [*Black Sally grassy low woodland in valleys in the Upper Slopes subregion of the NSW South-western Slopes bioregion and western South Eastern Highlands bioregion*] (Benson *et al.* 2010). No obvious equivalents from other numerical classifications.

Frequently occurring weeds: This vegetation is restricted to moist footslopes and alluvial margins, a relatively productive habitat prone to invasion by a range of exotic plant taxa. Although all plots are from conservation reserves, most of these high-country areas were historically seasonally grazed, and many common pasture weeds were recorded from more than 30% of plots assigned to this community: *Acetosella vulgaris* (0.75), *Anthoxanthum odoratum* (0.30), *Centaurium erythraea* (0.30), *Cirsium vulgare* (0.60), *Crepis capillaris* (0.70), *Holcus lanatus* (0.75), *Hypochaeris radicata* (0.80), *Rosa rubiginosa* (0.35), *Taraxacum officinale* (0.35), *Trifolium campestre* (0.45), *Trifolium repens* (0.70).

Threats: Some areas of this community at lower altitudes are likely to have been drowned by water impoundments of the Snowy scheme. However, the majority of its distribution is within conservation reserves (Kosciuszko NP and Namadgi NP). Grazed examples are likely to be prone to invasion by a range of exotic pasture plants and other weeds, due to moister habitat.

Reservation status: Recorded from Namadgi NP, Kosciuszko NP and Nimmo NR but probably extending into freehold land at Snowy Plain in the Southern Rivers CMA.

Extent of clearing: Extent of clearing unknown; some examples in deeper valley floors will have been drowned by major dams.

Reference: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney.

u158: Alpine Sallee shrub-grass subalpine mid-high woodland of the Australian Alps bioregion

Scientific Name: *Eucalyptus pauciflora* subsp. *niphophila / Tasmannia xerophila – Bossiaea foliosa – Hovea montana / Stellaria pungens – Oreomyrris eriopoda – Asperula scoparia*

Number of samples:	16
Richness [mean (±SD)]:	28 (6)
Slope (degrees):	(2) 9–14 (23)
Altitude (m asl):	(1398) 1541–1634 (1907)
Ave. Annual Rainfall (mm):	(1499) 1550–1649 (1910)
Temp. Annual Range (°C):	(21.1) 22–22.2 (23)

Vegetation Description: Community u158 is a mid-high woodland dominated by *Eucalyptus pauciflora* subsp. *niphophila.* The understorey is characterised by a discontinuous, though occasionally well-developed shrub layer often to 2 metres tall, dominated by *Bossiaea foliosa*, *Tasmannia xerophila*, *Podolobium alpestre*, *Olearia phlogopappa* and *Pimelea ligustrina* subsp. *ciliata*. The groundlayer is a mix of shrubs, grasses and forbs including *Hovea montana*, *Acrothamnus hookeri*, *Acrothamnus montanus*, *Poa phillipsiana*, *Stellaria pungens*, *Asperula scoparia*, *Oreomyrris eriopoda*, *Coronidium scorpioides*, *Senecio gunnii*, *Arthropodium milleflorum*, *Carex breviculmis*, *Gonocarpus montanus*, *Goodenia hederacea* subsp. *alpestris*, *Stylidium graminifolium sens. lat* and *Microseris lanceolata*.

Community u158 is largely confined to the Australian Alps bioregion, although small areas may be present in adjacent parts of the South Eastern Highlands bioregion. The community is widespread near the altitudinal limit of trees, and may be found in the vicinity of Thredbo, Charlottes

Plate u158: Community u158 in the hills above Charlottes Pass, dominated by stunted *Eucalyptus pauciflora* subsp. *niphophila* and an understorey of *Helichrysum rutidolepis*, *Olearia algida* and *Phebalium squamulosum* spp. *ozothamnoides*.

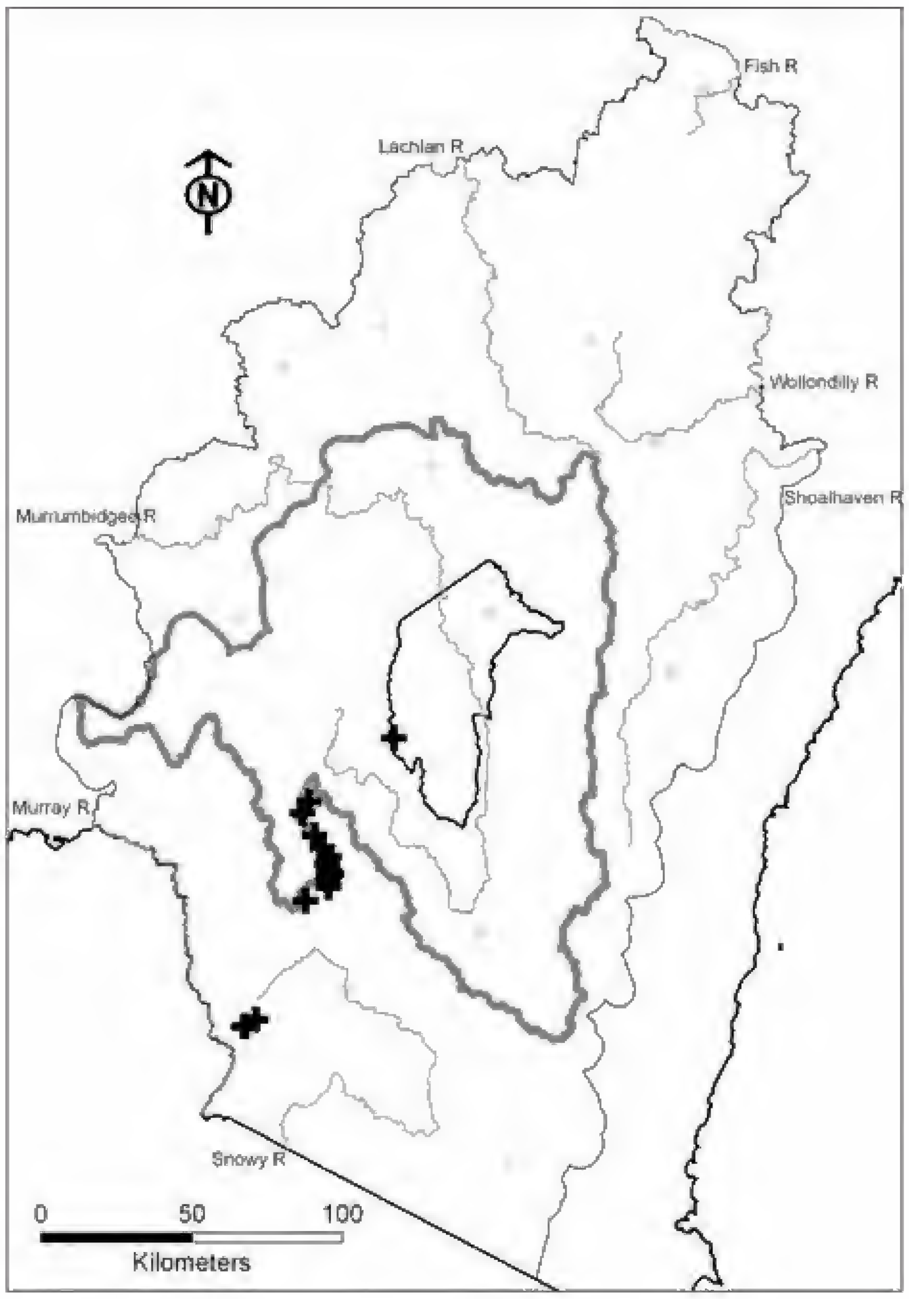

Fig. u158: Distribution of field samples assigned to this community.

Pass and Kiandra, and on the highest ranges in the ACT. It typically occurs on meta-sedimentary geologies, but is also found on granite and basalt. At its upper altitudinal limit, co-occurring communities include those typical of the alpine zone, especially Community a46 [*Prostanthera cuneata – Orites lancifolius – Nematolepis ovatifolia heathland of the Australian Alps bioregion*]. Elsewhere, the community occurs in association with Community u28 [*Snow Gum – Mountain Gum – Daviesia mimosoides tall dry grass-shrub subalpine open forest of the Australian Alps and South Eastern Highlands bioregions*] and in sheltered valleys, Community u40 [*Alpine Ash tall wet sclerophyll open forest primarily of the Australian Alps bioregion*].

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acaena novae-zelandiae	1	44	1	28	C
Aciphylla simplicifolia	1	38	1	2	P
Acrothamnus hookeri	1	56	1	8	P
Acrothamnus montanus	2	25	1	1	P
Arthropodium milleflorum	1	50	1	8	P
Asperula scoparia	1	69	2	22	P
Bossiaea foliosa	3	75	2	4	P
Brachyscome spathulata	1	44	1	11	P
Brachyscome spp.	1	25	1	1	P
Caladenia alpina	1	44	1	<1	P
Carex breviculmis	1	50	1	13	P
Celmisia spp.	2	25	1	<1	P
Coronidium scorpioides	2	63	1	20	P
Craspedia spp.	2	50	1	4	P
Eucalyptus pauciflora subsp. *niphophila*	3	94	2	<1	P
Gonocarpus montanus	1	50	1	1	P
Goodenia hederacea subsp. *alpestris*	1	50	2	16	P
Hovea montana	1	69	1	1	P
Lobelia pedunculata	1	44	1	5	P
Luzula densiflora	1	31	1	6	P
Microseris lanceolata	1	50	1	7	P
Olearia phlogopappa	2	44	1	3	P
Oreomyrrhis ciliata	1	31	1	2	P
Oreomyrrhis eriopoda	1	69	1	13	P
Ozothamnus thyrsoideus	1	25	1	2	P
Pimelea ligustrina subsp. *ciliata*	1	25	1	<1	P
Poa phillipsiana	3	31	2	3	P
Podolepis robusta	1	25	1	<1	P
Podolobium alpestre	1	50	2	2	P
Ranunculus graniticola	1	38	1	4	P
Senecio gunnii	1	63	1	9	P
Stellaria pungens	1	94	2	31	P
Stylidium graminifolium sens. lat	1	50	1	25	C
Tasmannia xerophila	2	56	1	1	P

Threatened communities: Nil.

Equivalent vegetation types: This community amalgamates VG128 [*Sub Alpine Dry Shrub/Herb Woodland*] with VG130 [*Sub-Alpine Shrub/Grass Woodland*], closely related communities previously described by Gellie (2005).

Frequently occurring weeds: The legacy of past clearing and cattle grazing is reflected in the presence and frequency with which common pastoral weeds were recorded. The most common weeds in this community are *Acetosella vulgaris* (0.81), *Hypochaeris radicata* (0.75) and *Taraxacum officinale* (0.38).

Threats: The threats facing this community are not unlike those experienced by other communities in the higher parts of Kosciuszko NP. The development of ski resorts and associated infrastructure, including ski runs resulted in significant clearing of the over-storey in some areas. Depending on the future expansion of ski fields, clearing may represent a future threat. Where the community occurs in close proximity to roads or tracks, invasion by exotic plant species including Ox-eye

Daisy (*Leucanthemum vulgare*), Sweet Vernal Grass (*Anthoxanthum odoratum*) and Orange Hawkweed (*Hieracium aurantiacum* subsp. *carpathicola*) is occurring. Grazing by feral herbivores, in particular horses, not only facilitates weed invasion via soil disturbance, but also affects groundlayer structre and species composition. Perhaps the most dramatic of all threats faced by this community is that of high fire frequency and intensity.

Reservation status: Almost entirely within conservation reserves, including Kosciuszko NP and Namadgi NP.

Extent of clearing: Historically, this community was extensively cleared to increase the area of optimal grazing land in leases. The extent of clearing is unknown but judging from historic aerial photography would have been many thousands of hectares. In most places, trees have re-invaded since the removal of grazing from Kosciuszko NP in the 1950s and 60s. In a few places, however, repeated tree removal and burning have changed this community into a disclimax shrubland.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u207: Jounama Snow Gum – Snow Gum shrubby mid-high woodland on granitoids primarily of the Namadgi region

Scientific Name: *Eucalyptus pauciflora* subsp. *debeuzevillei – Eucalyptus pauciflora* subsp. *pauciflora / Podolobium alpestre – Veronica perfoliata – Tasmannia xerophila / Poa sieberiana – Viola betonicifolia – Stellaria pungens – Coronidium scorpioides*

Number of samples:	24
Richness [mean (±SD)]:	24 (6)
Slope (degrees):	(3) 12–22 (32)
Altitude (m asl):	(1543) 1581–1680 (1745)
Ave. Annual Rainfall (mm):	(1186) 1271–1402 (1735)
Temp. Annual Range (°C):	(21.7) 22.2–22.7 (23)

Vegetation Description: Community u207 is a mid-high shrubby woodland dominated by *Eucalyptus pauciflora* subsp. *debeuzevillei* and *Eucalyptus pauciflora* subsp. *pauciflora*. The shrubby understorey is generally diverse, often including *Veronica perfoliata*, *Tasmannia xerophila*, *Podolobium alpestre*, *Daviesia ulicifolia*, *Oxylobium ellipticum*, *Olearia phlogopappa* and *Polyscias sambucifolia* subsp. *leptophylla*. *Acrothamnus hookeri* may be present. The groundlayer is a diverse mix of grasses and herbs, many of which occur in other high altitude communities. Typical species include *Poa sieberiana*, *Stellaria pungens*, *Viola betonicifolia*, *Coronidium scorpioides*, *Senecio gunnii*, *Asperula scoparia*, *Geranium potentilloides*, *Poranthera microphylla*, *Brachyscome spathulata*, *Acaena novae-zelandiae*, *Celmisia tomentella*, *Oreomyrris eriopoda*, *Dianella tasmanica*, *Wahlenbergia gloriosa* and *Arthropodium milleflorum*.

This community is almost entirely confined to the Upper Cotter and Yaouk Creek catchments of Namadgi NP and adjacent NSW parts of Kosciuszko NP, Bimberi NR and Scabby Range NR in the Australian Alps bioregion. It occurs in exposed locations at high altitude, primarily but not exclusively on northerly aspects. Although it is most common on granite, it is also known from metasedimentary geologies. A number of widespread montane communities occur in association with this community, including Community u22 [*Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands bioregions*], Community u23 [Snow Gum – *Epacris breviflora – Leptospermum myrtifolium tall woodland to open forest of drainage depressions primarily of the South Eastern Highlands bioregion*], Community u28 [*Snow Gum – Mountain Gum – Daviesia mimosoides tall dry grass-shrub subalpine open forest of the Australian Alps and South Eastern Highlands bioregions*] and

Plate u207: *Eucalyptus pauciflora* subsp. *debeuzevillei* with open *Poa sieberiana* patches characteristic of community u207. South-east of Snowy Flats off Mt. Franklin Road, Namadgi NP.

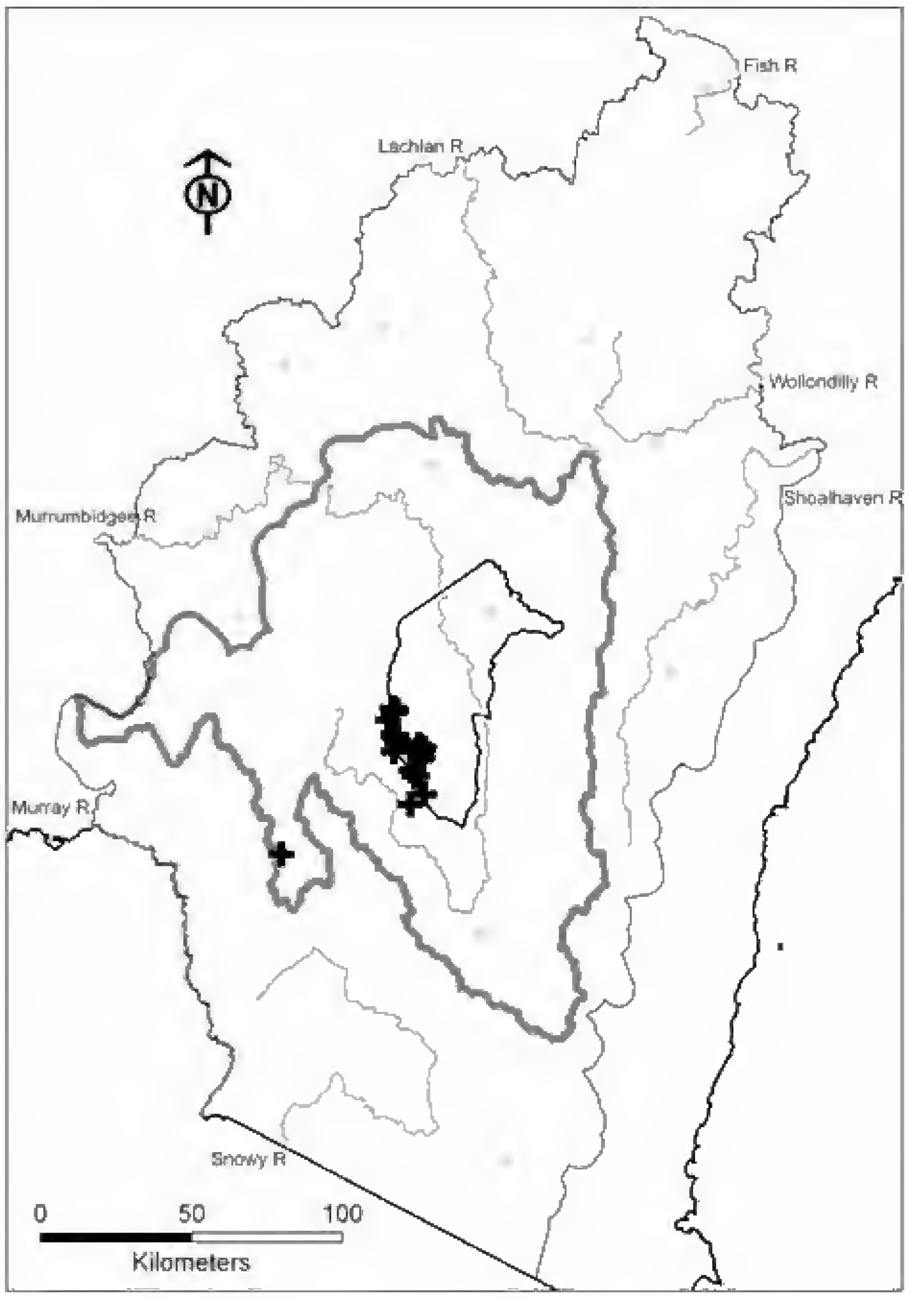

Fig. u207: Distribution of field samples assigned to this community.

Community u53 [*Mountain Gum – Blackwood tall wet sclerophyll open forest primarily on granitoids of the Australian Alps and western South Eastern Highlands bioregions*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia obliquinervia	2	21	1	3	P
Acrothamnus hookeri	2	46	1	8	P
Asperula scoparia	2	58	2	22	P
Brachyscome aculeata	1	33	1	2	P
Brachyscome spathulata	2	38	1	11	P
Celmisia tomentella	2	33	1	<1	P
Coronidium scorpioides	2	75	1	19	P
Craspedia spp.	2	33	1	4	P
Daviesia ulicifolia	2	46	1	10	P
Eucalyptus pauciflora subsp. *debeuzevillei*	4	54	1	<1	P
Geranium potentilloides	2	50	1	13	P
Leucopogon gelidus	1	29	1	2	P
Olearia megalophylla	2	42	1	5	P
Olearia phlogopappa	1	42	1	3	P
Oxylobium ellipticum	3	46	1	4	P
Ozothamnus thyrsoideus	2	29	1	2	P
Picris angustifolia subsp. *angustifolia*	1	21	1	2	P
Podolepis robusta	2	21	1	<1	P
Podolobium alpestre	2	54	2	2	P
Polyscias sambucifolia subsp. *leptophylla*	3	38	2	4	P
Senecio gunnii	1	75	1	9	P
Stellaria pungens	2	88	2	31	P
Tasmannia xerophila	2	50	1	1	P
Veronica derwentiana	2	33	1	7	P
Veronica perfoliata	2	54	1	4	P
Viola betonicifolia	2	92	1	27	P
Wahlenbergia gloriosa	1	29	1	2	P
Eucalyptus pauciflora subsp. *pauciflora*	4	42	3	21	C
Poa sieberiana	3	71	2	48	C
Poranthera microphylla	2	46	1	27	C

Threatened communities: Nil.

Equivalent vegetation types: This community is similar to VG127 [*Sub-Alpine Dry Shrub/Herb/Grass Woodland*] previously described by Gellie (2005).

Frequently occurring weeds: Weeds are not common in this community, with only *Hypochaeris radicata* (0.33), a widespread species with high colonising potential, occurring in a large number of plots.

Threats: Grazing by feral herbivores and frequent and intense fire are the major threats faced by this community.

Reservation status: Likely to be confined to conservation reserves including Bimberi NR, Kosciuszko NP, Namadgi NP, Scabby Range NR and Yaouk NR.

Extent of clearing: Unlikely to have been significant because of the remoteness of this community and the landscape position upon which it is generally found.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Class: Southern Tableland Grassy Woodlands

p24: Yellow Box – Blakely's Red Gum tall grassy woodland on undulating sedimentary and acid-volcanic substrates in the Goulburn area of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus melliodora* ± *Eucalyptus blakelyi – Eucalyptus mannifera – Eucalyptus dives / Acacia decurrens / Lissanthe strigosa – Pimelea curviflora / Lomandra filiformis* subsp. *coriacea – Microlaena stipoides – Poa sieberiana – Gonocarpus tetragynus*

Number of samples:	28
Richness [mean (±SD)]:	29 (9)
Slope (degrees):	(0) 2–4 (9)
Altitude (m asl):	(615) 647–705 (815)
Ave. Annual Rainfall (mm):	(654) 670–697 (734)
Temp. Annual Range (°C):	(25.7) 26.1–26.6 (26.7)

Vegetation Description: Community p24 is a tall grassy open eucalypt woodland, with a medium to low tree canopy commonly containing *Eucalyptus blakelyi* and/or *Eucalyptus melliodora*, with other tableland eucalypts occurring less frequently including *Eucalyptus dives*, *Eucalyptus mannifera*, *Eucalyptus macrorhyncha* and *Eucalyptus rubida*. A sparse to patchy shrub stratum may be present, commonly with tall *Acacia decurrens* and smaller dry shrubs including *Acacia genistifolia* and *Daviesia latifolia*. The groundlayer in this community is generally dominated by a diverse suite of grasses including *Microlaena stipoides*, *Poa sieberiana*, *Themeda australis* and various *Aristida*, *Rytidosperma*, *Austrostipa* and *Dichelachne* species. A rich mix of forbs includes *Lomandra filiformis* subsp. *coriacea*, *Chrysocephalum apiculatum*, *Lomandra multiflora*, *Einadia nutans*, *Hydrocotyle laxiflora* , *Gonocarpus tetragynus*, *Goodenia hederacea* subsp. *hederacea*, *Plantago debilis* and *Dianella revoluta*. A sparse scatter of low tough shrubs (commonly *Lissanthe strigosa*, *Melichrus urceolatus*, *Pimelea curviflora* and *Bossiaea buxifolia* is often present.

This community is defined from field survey plots scattered across the relatively low, dry saddle of the great divide around Goulburn. Plots assigned to this community are located in an area bounded by Woodhouselee, Gundaroo, Manar, Kooringaroo and Canyonleigh (and extending east of the study area), and occur on gently undulating tableland country on relatively deep soils of moderately low fertility derived from volcanic rocks (porphyry, rhyolites and tuffs) and from ancient sediments/metasediments (greywacke, limestone, shale, siltstone, quartzite including Gundary and Towrang beds and various Adaminaby group strata).

Community p24 commonly grades into Community p23 [*Red Stringybark – Broad-leaved Peppermint tall dry sclerophyll grassy open forest on loamy rises primarily in the Bungonia subregion of the South Eastern Highlands bioregion*] on footslopes of hilly country with shallower soils, or into Community u78 [*Snow Gum grassy mid-high woodland of the South Eastern Highlands bioregion*] in cooler situations and/or with increasing elevation. In similar rolling country to the west with decreasing rainfall, this community is replaced by Community u19 [*Blakely's Red Gum – Yellow Box ± White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands bioregions*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia decurrens	2	46	1	1	P
Acacia genistifolia	2	39	1	1	P
Aristida ramosa	2	29	2	5	P
Aristida vagans	2	21	2	1	P
Asperula conferta	2	39	1	11	P
Austrostipa scabra	2	25	2	<1	P
Bossiaea buxifolia	2	29	1	7	P
Cassinia arcuata	2	25	1	1	P
Cassinia laevis	1	21	2	1	P
Cheilanthes sieberi	2	29	1	9	P
Chrysocephalum apiculatum	2	61	1	6	P
Chrysocephalum semipapposum	1	21	1	4	P
Dichelachne micrantha	1	29	1	10	P
Einadia nutans	2	50	1	4	P
Eucalyptus blakelyi	3	36	3	2	P
Eucalyptus melliodora	3	54	3	5	P
Goodenia hederacea subsp. *hederacea*	2	50	2	16	P
Hydrocotyle laxiflora	2	61	2	29	P
Juncus usitatus	1	21	1	<1	P
Lissanthe strigosa	2	64	1	6	P
Lomandra filiformis subsp. *coriacea*	2	93	2	18	P
Lomandra multiflora	1	54	1	18	P
Melichrus urceolatus	1	39	1	13	P
Microlaena stipoides	2	82	2	34	P
Opercularia aspera	2	36	1	3	P
Pimelea curviflora	1	54	1	6	P
Plantago debilis	2	46	2	4	P
Poa sieberiana	2	79	2	48	P
Pterostylis spp.	2	21	1	6	P
Rytidosperma laeve	3	32	2	4	P
Rytidosperma racemosum	2	21	2	<1	P
Themeda australis	2	64	2	21	P
Tricoryne elatior	1	36	1	4	P
Wahlenbergia luteola	1	29	1	1	P
Dianella revoluta	2	43	1	22	C
Gonocarpus tetragynus	2	68	2	48	C

Threatened communities: This community is part of TSC Act 1995 – *White Box Yellow Box Blakely's Red Gum Woodland* and EPBC Act 1999 – *White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derived Native Grassland.*

Equivalent vegetation types: Represents GWp24 [*Tableland Grassy Box – Gum Woodland*] (Tozer *et al.* 2010) in the context of the upper Murrumbidgee catchment, and includes a westward extension with the addition of new plots near Gundaroo. The current study area included some 63 of the 80 plots assigned to GWp24 by Tozer *et al.* (2010). There are no related Forest Ecosystems, with this community defined almost entirely by plots which were not classified by Gellie (2005).

Frequently occurring weeds: Weeds recorded in this community are typical of those found in other over-grazed grassy woodlands of the South Eastern Highlands bioregion. The most frequently recorded species are *Arctotheca calendula* (0.25), *Briza maxima* (0.21), *Bromus catharticus* (0.21), *Dactylis glomerata* (0.25), *Hypochaeris radicata* (0.63), *Paspalum dilatatum* (0.29), *Plantago lanceolata* (0.33) and *Rosa rubiginosa* (0.33).

Threats: This community occurs on undulating tableland country that was historically developed for stock grazing by the clearing of trees and shrubs and widespread conversion of groundlayer to pastures dominated by exotic annual grasses and legumes. Remnants are often regularly grazed and subject to ongoing invasion by exotic plants and feral animals. The condition of remnants adjacent to or within urban centres is generally declining because of recreational disturbances, firewood removal, over-grazing by domestic, feral and native herbivores and severe weed invasion. Urban and rural-residential development is also responsible for recent and predicted future clearing of remnant vegetation.

Plate p24: Grazed and partially cleared example of Community p24 on a crown reserve east of Tarlo River NP (plot CAN038LQ).

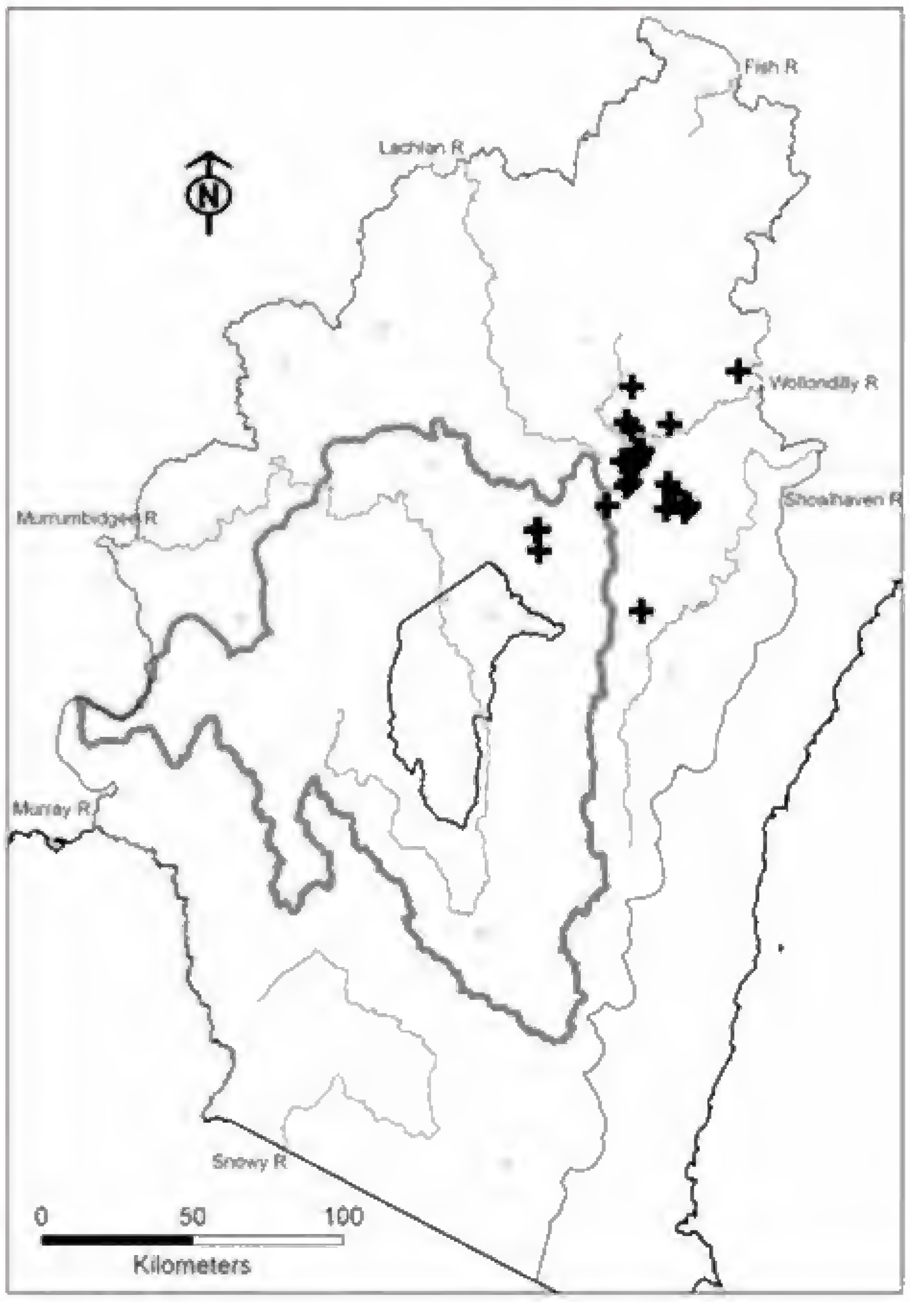

Fig. p24: Distribution of field samples assigned to this community

Reservation status: Due to the agriculturally desirable habitat of this community, it is very poorly represented in conservation reserves. The only samples from a conservation reserve are at the margins of cleared country in McLeod's Creek NR near Gundaroo.

Extent of clearing: The broad geographic distribution of small remnants and isolated paddock trees suggest that historically, this community was extensively cleared.

References: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

u19: Blakely's Red Gum – Yellow Box ± White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands bioregions

Scientific Name: *Eucalyptus blakelyi – Eucalyptus melliodora ± Eucalyptus albens / Microlaena stipoides – Rytidosperma racemosum – Elymus scaber – Themeda australis – Austrostipa scabra*

Number of samples:	28
Richness [mean (±SD)]:	26 (10)
Slope (degrees):	(0) 2–5 (29)
Altitude (m asl):	(267) 469–593 (811)
Ave. Annual Rainfall (mm):	(646) 681–829 (1023)
Temp. Annual Range (°C):	(25.6) 26.7–28.1 (29)

Vegetation Description: Community u19 is a tall grassy eucalypt woodland dominated by *Eucalyptus blakelyi* and/or *Eucalyptus melliodora* with occasional occurrences of *Eucalyptus albens*. In the western part of its range, *Eucalyptus albens* can be the dominant eucalypt. The shrub layer is sparse or absent and generally contains regenerating eucalypts, *Acacia implexa* and/or *Acacia dealbata*. The groundlayer is dominated by grasses including *Microlaena stipoides*, *Elymus scaber*, *Themeda australis*, *Rytidosperma racemosum*, *Bothriochloa macra* and *Poa sieberiana*, with degraded areas generally dominated by less palatable robust species such as *Bothriochloa macra* and *Austrostipa scabra*. Forbs include *Hydrocotyle laxiflora*, *Rumex brownii*, *Geranium solanderi*, *Oxalis perennans*, *Lomandra filiformis* subsp. *coriacea* and *Tricoryne elatior*. Relatively undisturbed sites tend to have a wide variety of forbs including *Microtis unifolia*, *Arthropodium minus*, *Dichopogon fimbriatus* and *Wurmbea dioica*.

This community occurs on flat and undulating fertile soils from north of Crookwell in the east to west of Tumut in the Upper Slopes subregion of the NSW South Western Slopes bioregion. Plot analysis post this study suggests that community u19 is also present in the northern ACT. To the east, it may grade into Community p24 [*Yellow Box – Blakely's Red Gum tall grassy woodland on undulating sedimentary and acid-volcanic substrates in the Goulburn area of the South Eastern Highlands bioregion*] and Community u178 [*Yellow Box ± Apple Box tall grassy woodland of the South Eastern Highlands*] to the south-east in the ACT. West of the study area, this community grades into a number of Box-Gum woodland associations including the closely related VCA 277 [*Blakely's Red Gum – Yellow Box grassy tall woodland of the NSW South-western Slopes bioregion*] and, primarily in the South Western Slopes bioregion, the *Eucalyptus albens* dominated VCA 266 [*White Box grassy woodland in the Upper Slopes subregion of the NSW South-western Slopes bioregion*] described by Benson *et al.* (2010).

Plate u19: Community u19 with *Eucalyptus melliodora* and a grassy understorey of *Themeda australis* and *Rytidosperma racemosum*. Goorooyaroo NR.

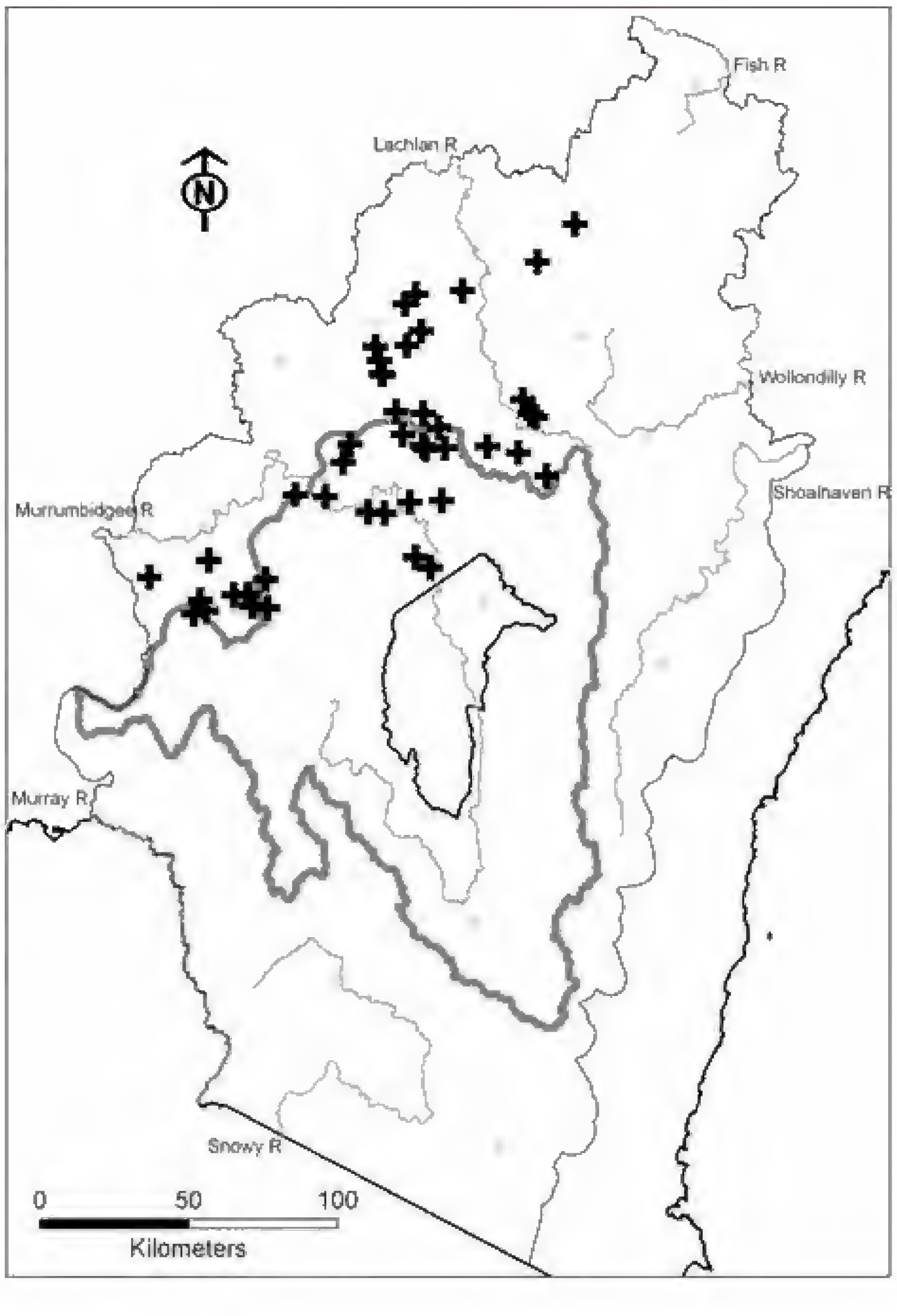

Fig. u19: Distribution of field samples assigned to this community.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acaena echinata	1	29	1	9	P
Aristida ramosa	2	46	2	5	P
Arthropodium minus	1	29	1	1	P
Austrostipa scabra	2	46	1	4	P
Bothriochloa macra	2	57	1	3	P
Carex inversa	1	36	1	8	P
Convolvulus angustissimus	1	25	1	3	P
Crassula sieberiana	1	21	1	5	P
Dichopogon fimbriatus	1	29	1	<1	P
Drosera peltata	1	21	1	1	P
Elymus scaber	2	75	1	21	P
Eucalyptus albens	4	32	3	<1	P
Eucalyptus blakelyi	3	61	2	2	P
Eucalyptus melliodora	3	57	3	5	P
Geranium solanderi	1	61	1	19	P
Hydrocotyle laxiflora	1	68	2	29	P
Lomandra filiformis subsp. *coriacea*	1	50	2	19	P
Microlaena stipoides	3	86	2	34	P
Microtis unifolia	1	32	1	4	P
Oxalis perennans	1	57	1	13	P
Panicum effusum	1	29	1	3	P
Rumex brownii	1	68	1	9	P
Rytidosperma erianthum	2	32	1	<1	P
Rytidosperma pilosum	2	29	2	9	P
Rytidosperma racemosum	2	50	2	10	P
Schoenus apogon	1	32	1	5	P
Solenogyne dominii	1	39	1	3	P
Themeda australis	3	54	2	21	P
Tricoryne elatior	1	50	1	3	P
Wurmbea dioica	1	25	1	3	P
Gonocarpus tetragynus	1	43	2	48	C
Poa sieberiana	1	57	2	48	C

Threatened communities: This community is part of the TSC Act 1995 – *White Box Yellow Box Blakely's Red Gum Woodland*; EPBC Act 1999 – *White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derived Native Grassland*; and NC Act 1980 – *Yellow Box/Red Gum Grassy Woodland.*

Equivalent vegetation types: This community is most similar to VCA 277 [*Blakely's Red Gum – Yellow Box grassy tall woodland of the NSW South-western Slopes bioregion*] (Benson *et al.* 2010) and is similar to a number of communities described by Gellie (2005) including VG116, VG117, VG154 and VG160. At the western edge of its range, there may be areas dominated by *Eucalyptus albens*, and in this instance it will be most akin to VCA 266 [*White Box grassy woodland in the Upper Slopes subregion of the NSW South-western Slopes bioregion*] (Benson *et al.* 2010).

Frequently occurring weeds: Most remnants of this community are found on freehold land and actively managed as a source of food and shelter for domestic stock. As a consequence of this, many remnants are now infested with common pasture weeds including *Briza maxima* (0.63), *Briza minor* (0.67), *Bromus diandrus* (0.56), *Bromus molliformis* (0.59), *Cirsium vulgare* (0.48), *Cynosurus echinatus* (0.37), *Echium plantagineum* (0.33), *Hypericum perforatum* (0.7), *Hypochaeris glabra* (0.52), *Hypochaeris radicata* (0.7), *Lolium perenne* (0.44), *Lysimachia arvensis* (0.33), *Orobanche minor* (0.41), *Petrorhagia nanteuilii* (0.59), *Plantago lanceolata* (0.48), *Romulea rosea* var. *australis* (0.33), *Rosa rubiginosa* (0.33), *Sherardia arvensis* (0.44), *Trifolium angustifolium* (0.63), *Trifolium arvense* (0.52), *Trifolium campestre* (0.56), *Trifolium dubium* (0.48), *Trifolium striatum* (0.41), *Trifolium subterraneum* (0.52) and *Vulpia muralis* (0.37).

Threats: Because this community naturally occurs on soils of high fertility, it has experienced high levels of clearing. Remnants are often subjected to ongoing grazing by domestic stock, the addition of fertiliser and exotic pasture species, firewood removal and invasion by weed and pest species. The extent of disturbance has severely compromised the condition of most remnants of this community across its range. As a result, there are very few examples with an intact over-storey, high native plant species richness, low exotic weed species richness and abundance, over-storey regeneration and high structural integrity.

Reservation status: Poorly conserved. Examples are found in Burrinjuck NR, as well as Dunlop NR and Goorooyaroo NR in the ACT.

Extent of clearing: Known to be highly cleared. Due to continued and intense grazing, large areas containing healthy, regenerating overstorey species are rare.

References: Benson, J.S., Richards, P.G., Waller, S. & Allen, C.B. (2010) New South Wales vegetation classification and assessment: Part 3. Plant communities of the NSW Brigalow Belt South, Nandewar and west New England bioregions and update of NSW Western Plains and South Western Slopes plant communities. Version 3 of the NSW VCA database. *Cunninghamia* 11: 457–579. Botanic Gardens Trust, Sydney; Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

u20: *Brachychiton populneus – Bursaria spinosa – Themeda australis* shrub-grass mid-high open woodland on limestone karsts in the Wee Jasper area

Scientific Name: *Brachychiton populneus – Eucalyptus bridgesiana / Grevillea iaspicula – Bursaria spinosa / Themeda australis – Poa sieberiana – Imperata cylindrica*

Number of samples:	3
Richness [mean (±SD)]:	35 (6)
Slope (degrees):	(1) 3–8 (12)
Altitude (m asl):	(375) 377–407 (436)
Ave. Annual Rainfall (mm):	(850) 851–875 (897)
Temp. Annual Range (°C):	(26.2) 26.4–26.5 (26.5)

Vegetation Description: Community u20 is a mid-high open woodland with sparsely scattered trees of *Brachychiton populneus* and *Eucalyptus bridgesiana* with occasional *Eucalyptus albens* and *Eucalyptus melliodora.* It has a moderately dense tall shrub layer commonly dominated by *Bursaria spinosa.* Other co-occurring shrub species include *Grevillea iaspicula* (Critically Endangered under the TSC Act 1995), *Dodonaea viscosa*, *Rubus parviflora*, *Indigophora signata*, *Discaria pubescens* and *Olearia* spp.. There is often a dense grassy groundlayer dominated by *Themeda australis* and *Poa sieberiana.* Other groundlayer species include *Imperata cylindrica*, *Microlaena stipoides*, *Bulbine glauca*, *Cymbopogon refractus*, *Sorghum leiocladum* and *Rytidosperma* spp. While many of the taxa recorded in ths community are regionally uncommon, the presence of *Imperata cylindrica* is notable in that it is generally known primarily from the coast and the Nandewar bioregion.

This community is highly restricted in distribution, being endemic to limestone karst formations from just south of Wee Jasper to Lake Burrinjuck. The soil is a skeletal to shallow red-brown loam. Driven by geology rather than landform, it occurs on all aspects and the terrain varies from flat to gently sloping to very steep. At some sites within the karst there are large sinkholes or low cliffs where components of the vegetation grow on almost vertical limestone formations.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Arthropodium milleflorum	1	100	1	8	P
Arthropodium minus	1	33	1	1	P
Asperula ambleia	1	33	1	<1	P
Bothriochloa macra	1	100	1	3	P
Brachychiton populneus	2	100	1	2	P
Bulbine glauca	1	100	1	<1	P
Bursaria spinosa	2	100	1	10	P
Carex incomitata	1	33	1	1	P

Plate u20: Community u20 with *Grevillea iaspicula* on limestone outcrops in foreground, on private property 2 km south of Wee Jasper.

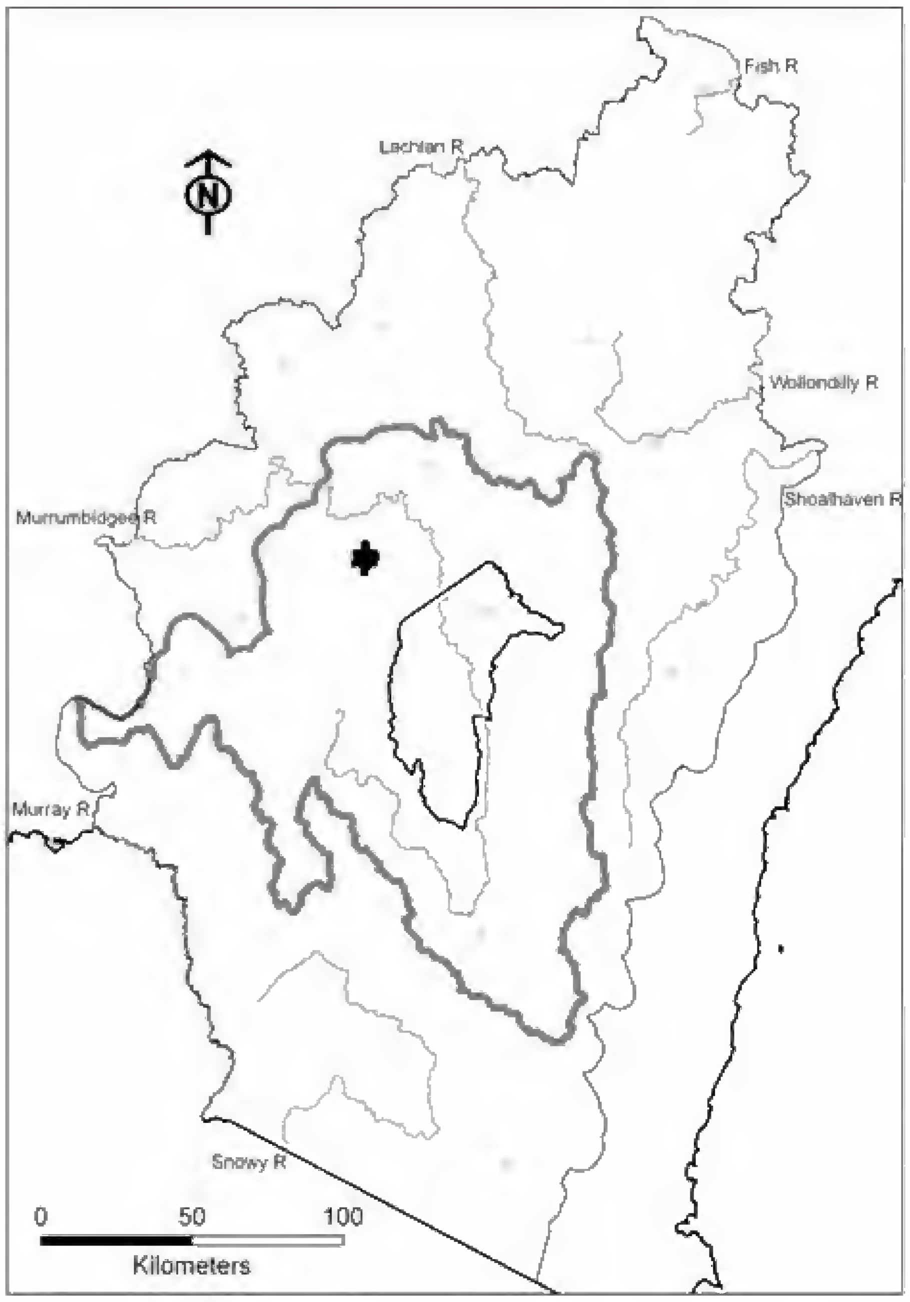

Fig. u20: Distribution of field samples assigned to this community.

Clematis microphylla	2	67	1	<1	P
Convolvulus angustissimus	1	67	1	3	P
Correa reflexa	1	33	1	<1	P
Daucus glochidiatus	1	100	1	8	P
Dianella longifolia	1	67	1	3	P
Discaria pubescens	1	33	1	<1	P
Dodonaea viscosa	1	67	1	2	P
Echinopogon cheelii	1	33	1	1	P
Elymus scaber	1	100	1	21	P
Eucalyptus bridgesiana	2	67	3	7	P
Geranium solanderi	1	100	1	19	P
Glycine clandestina	1	100	1	30	P
Glycine tabacina	1	67	1	4	P
Grevillea iaspicula	1	100	0	0	P
Hydrocotyle laxiflora	1	100	2	30	P
Imperata cylindrica	1	100	2	<1	P
Indigofera adesmiifolia	1	67	1	<1	P
Microtis spp.	1	33	1	<1	P
Olearia spp.	1	33	1	<1	P
Pleurosorus rutifolius	1	67	1	<1	P
Poa sieberiana	1	100	2	48	P
Senecio quadridentatus	1	67	1	6	P
Themeda australis	4	100	2	21	P
Wahlenbergia spp.	1	67	1	5	P
Desmodium varians	1	67	1	12	C
Dichondra repens	1	67	2	21	C
Rubus parvifolius	2	67	1	11	C
Rytidosperma racemosum	1	67	2	10	C

Threatened communities: Not currently listed, but possibly eligible for listing as Critically Endangered due to its highly restricted distribution and current / historic threats. Areas with *Eucalyptus albens* or *Eucalyptus melliodora* and a grassy understorey are considered part of TSC Act 1995 – *White Box Yellow Box Blakely's Red Gum Woodland* and EPBC Act 1999 – *White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derived Native Grassland.*

Equivalent vegetation types: Nil. Poory sampled community.

Frequently occurring weeds: This community appears to be highly susceptible to weed invasion. Weeds were abundant at most sites, demonstrating the extent of past grazing disturbance, and also the sensitivity of the community to that disturbance. The most common weeds recorded were *Briza minor* (0.33), *Bromus diandrus* (0.33), *Bromus molliformis* (0.33), *Bromus tectorum* (0.67), *Carthamus lanatus* (1.00), *Centaurium erythraea* (1.00), *Cerastium glomeratum* (0.33), *Chondrilla juncea* (0.67), *Cirsium vulgare* (0.33), *Cotoneaster glaucophyllus* (0.33), *Cynosurus echinatus* (0.33), *Hypericum perforatum* (1.00), *Hypochaeris radicata* (0.67), *Lactuca serriola* (1.00), *Lysimachia arvensis* (0.67), *Petrorhagia nanteuilii* (0.33), *Pyracantha angustifolia* (0.33), *Rosa rubiginosa* (1.00), *Rubus fruticosus* sp. agg. (1.00), *Torilis nodosa* (0.67), *Trifolium angustifolium* (0.33), *Trifolium arvense* (0.33), *Trifolium campestre* (0.33) and *Vulpia myuros f. megalura* (0.33), all of which are widespread throughout the region.

Threats: Highly threatened and few relatively intact examples remain. Previous clearing and heavy grazing by domestic stock have almost completely destroyed the tree and shrub layer from all but the most rocky sites where stock have had difficulty gaining access. Some of the sites which have escaped intensive stock grazing are now heavily invaded by *Rubus fruticosus* sp. agg. and *Rosa rubiginosa* and other exotic shrubs such as *Cotoneaster* spp. and *Photinia serratifolia.* Many sites also have significant infestations of *Hypericum perforatum* on their margins where there has been greater disturbance due to grazing.

Reservation status: Extremely poorly represented within conservation reserves. A small area of one to two hectares occurs in Burrinjuck NR on the southern shores of Lake Burrinjuck. Unfortunately the shrub and groundlayer in this part of the reserve have been significantly degraded due to feral goat browsing.

Extent of clearing: It is estimated that over 90% of karst habitat has been cleared in the region, with only approximately 10 hectares remaining in reasonably intact condition.

u178: Yellow Box – Apple Box tall grassy woodland of the South Eastern Highlands

Scientific Name: *Eucalyptus melliodora – Eucalyptus bridgesiana / Austrostipa scabra – Themeda australis – Panicum effusum – Chrysocephalum apiculatum – Oxalis perennans*

Number of samples:	33
Richness [mean (±SD)]:	46 (11)
Slope (degrees):	(1) 3–9 (18)
Altitude (m asl):	(613) 662–759 (862)
Ave. Annual Rainfall (mm):	(571) 638–664 (699)
Temp. Annual Range (°C):	(26.2) 26.5–27 (27.5)

Vegetation Description: Community u178 is a tall grassy eucalypt woodland characterised by *Eucalyptus melliodora* and/or *Eucalyptus bridgesiana*, occasionally with *Eucalyptus blakelyi* along creeklines and in moist depressions. In the southern extent of its range scattered occurrences of *Eucalyptus rubida* are increasingly common. Whilst often containing a mix of these species, some examples may be dominated entirely by *Eucalyptus melliodora* or *Eucalyptus bridgesiana*. The shrub layer is sparse or absent and may include *Acacia dealbata*, with low shrubs such as *Melichrus urceolatus*, *Astroloma humifusum* and *Cryptandra amara* occurring on less fertile sites. The groundlayer is dense and dominated by herbaceous taxa, with grasses including *Themeda australis*, *Austrostipa scabra*, *Poa sieberiana*, *Panicum effusum* and *Elymus scaber.* Forbs include *Oxalis perennans*, *Hydrocotyle laxiflora*, *Acaena ovina*, *Desmodium varians*, *Chrysocephalum apiculatum*, *Cymobonotus lawsonianus*, *Geranium solanderi* and *Glycine tabacina.*

This community occurs from the Lake George area south to Michelago / Bredbo. It is generally found on fertile valley soils, although it may extend upslope. It is likely to have been widely distributed throughout the northern half of the ACT prior to urban expansion. In the ACT and surrounds, it often occurs downslope of less fertile communities such as Community u66 [*Mealy Bundy – Red Stringybark grass-herb mid-high open forest of the South Eastern Highlands and Upper Slopes subregion of the South Western Slopes bioregion*] and Community p14 [*Red Stringybark – Scribbly Gum – Rytidosperma pallidum tall grass-shrub dry sclerophyll open forest on loamy ridges of the central South Eastern Highlands bioregion*]. Further south around Bredbo, it often occurs downslope of Community u29 [*Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acaena ovina	1	79	1	7	P
Aristida ramosa	1	33	2	5	P
Arthropodium minus	1	24	1	1	P
Asperula conferta	1	36	1	11	P
Astroloma humifusum	1	21	1	5	P
Austrostipa bigeniculata	1	27	2	<1	P
Austrostipa scabra	1	82	2	3	P
Bothriochloa macra	1	45	1	3	P
Bulbine bulbosa	1	24	1	4	P
Carex inversa	1	33	1	8	P
Cheilanthes sieberi	1	39	1	9	P
Chrysocephalum apiculatum	1	70	1	5	P
Chrysocephalum semipapposum	1	21	1	4	P
Convolvulus angustissimus	1	39	1	3	P
Crassula sieberiana	1	55	1	5	P
Cymbonotus lawsonianus	1	67	1	4	P
Cynoglossum suaveolens	1	30	1	3	P
Daucus glochidiatus	1	64	1	8	P
Desmodium varians	1	79	1	12	P
Dichelachne micrantha	1	33	1	10	P

Plate u178: An example of Community u178 dominated by *Eucalyptus melliodora* with a grassy understorey, Campbell Park, Canberra.

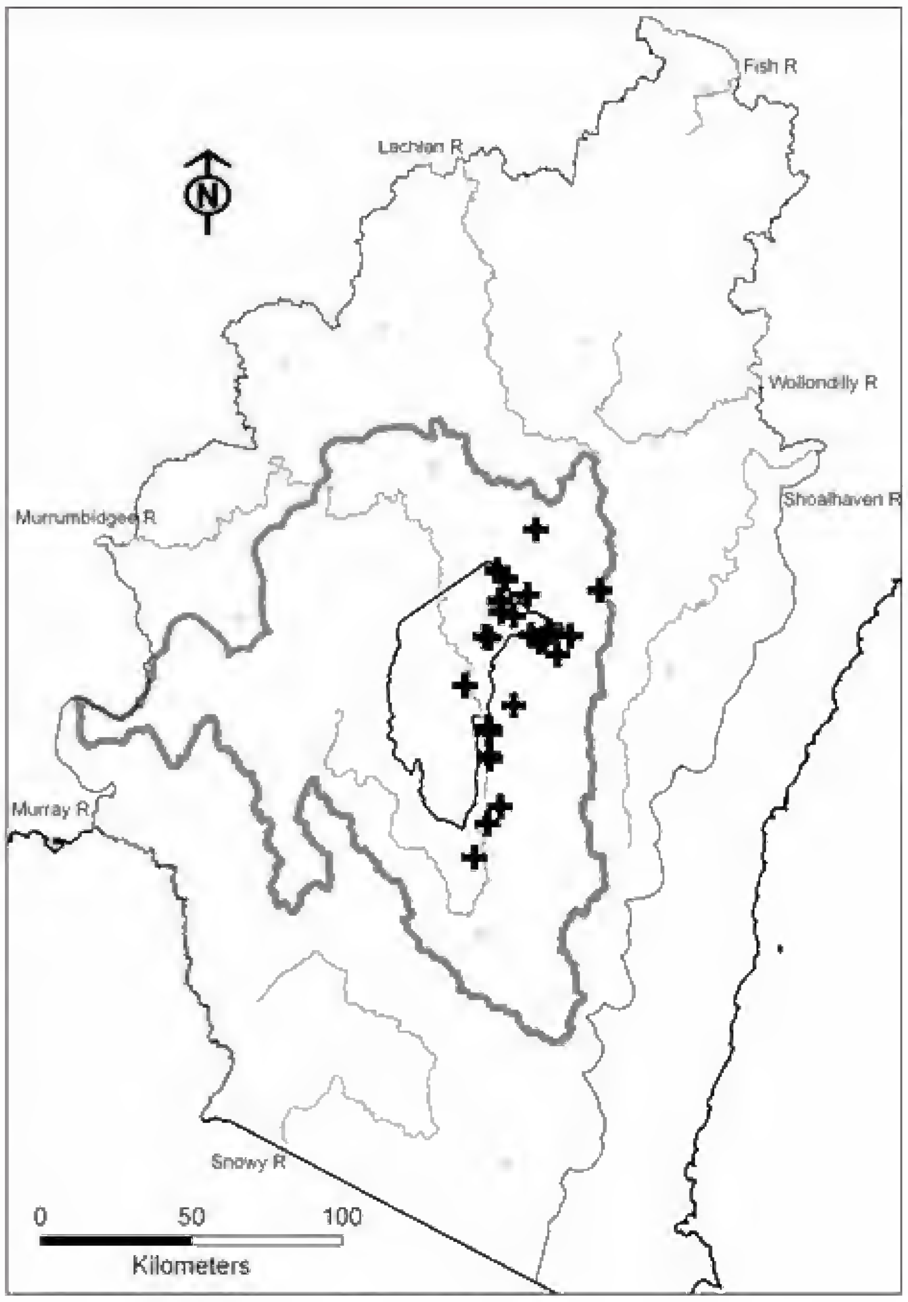

Fig. u178: Distribution of field samples assigned to this community.

Einadia nutans	1	48	1	4	P
Elymus scaber	1	61	1	21	P
Enneapogon nigricans	1	27	1	<1	P
Eryngium ovinum	1	21	1	<1	P
Eucalyptus blakelyi	2	21	3	2	P
Eucalyptus bridgesiana	3	52	3	7	P
Eucalyptus melliodora	3	58	3	5	P
Euchiton involucratus	1	33	1	3	P
Euchiton sphaericus	1	24	1	7	P
Euchiton spp.	1	24	1	<1	P
Geranium solanderi	1	67	1	19	P
Glycine tabacina	1	61	1	3	P
Hydrocotyle laxiflora	1	88	2	29	P
Hypericum gramineum	1	67	1	25	P
Leptorhynchos squamatus	1	33	1	3	P
Lomandra filiformis	1	48	1	2	P
Lomandra multiflora	1	42	1	18	P
Melichrus urceolatus	1	48	1	13	P
Oxalis perennans	1	85	1	13	P
Panicum effusum	1	67	1	3	P
Pimelea curviflora	1	39	1	6	P
Plantago gaudichaudii	1	27	1	1	P
Plantago varia	1	58	1	11	P
Poa sieberiana	1	76	2	48	P
Rumex brownii	1	67	1	9	P
Rytidosperma spp.	2	52	1	7	P
Schoenus apogon	1	33	1	5	P
Sebaea ovata	1	21	1	<1	P
Senecio quadridentatus	1	33	1	5	P
Solenogyne dominii	1	58	1	3	P
Themeda australis	2	79	2	20	P
Tricoryne elatior	1	36	1	4	P
Triptilodiscus pygmaeus	1	30	1	<1	P
Vittadinia cuneata	1	21	1	2	P
Vittadinia muelleri	1	58	1	1	P
Wahlenbergia communis	1	45	1	4	P
Wahlenbergia spp.	1	48	1	5	P
Wurmbea dioica	1	45	1	2	P
Gonocarpus tetragynus	1	64	2	48	C
Microlaena stipoides	1	55	2	34	C

Threatened communities: This community is part of the TSC Act 1995 – *White Box Yellow Box Blakely's Red Gum Woodland*; EPBC Act 1999 – *White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derived Native Grassland;* NC Act 1980 – *Yellow Box/Red Gum Grassy Woodland.*

Equivalent vegetation types: This community is mostly made up of new plots but includes some plots which were used to define VG160 [*Western Slopes Dry Grass Woodland*] (Gellie 2005).

Frequently occurring weeds: The most frequently recorded weeds are also those found in other over-grazed grassy woodlands of the South Eastern Highlands bioregion, including *Acetosella vulgaris* (0.31), *Centaurium erythrae*a (0.53), *Hypochaeris radicata* (0.81), *Linaria arvensis* (0.31), *Petrorhagia nanteuilii* (0.88), *Plantago lanceolata* (0.38), *Rosa rubiginosa* (0.59), *Trifolium arvense* (0.81), *Trifolium campestre* (0.38) and *Vulpia myuros f. megalura* (0.44).

Threats: This vegetation type has been extensively cleared for various agricultural purposes, including cropping and grazing. In the ACT, urban development was, and continues to be the catalyst for further clearing of this community. Because of its distribution on the flat, fertile and well-watered parts of the landscape, most remaining remnants are subject to intensive domestic stock grazing and weed invasion. As a consequence the majority of remnants now contain a depauperate native groundlayer and shrub/midstorey.

Reservation status: Unknown, although small patches of this community are occur in the Mt. Majura, Mt. Ainslie and Mugga Mugga sections of Canberra Nature Park, and Stony Creek NR in NSW. Very small remnants may be present in Mulligans Flat NR and Goorooyarroo NR.

Extent of clearing: Not fully assessed, but given its occurrence on fertile soils and distribution across urban and peri-urban areas it is considered to be one of the most highly cleared and modified components of the Box-Gum alliance.

Reference: Gellie, N.J.H. (2005) Native vegetation of the southern forests: South Eastern Highlands, Australian Alps, South West Slopes and South East Corner bioregions. *Cunninghamia* 9: 219–254.

Class: Tableland Clay Grassy Woodlands

p220: Ribbon Gum – Snow Gum tableland flats tall grassy woodland primarily on granitoids in the Kybean – Gourock and Monaro subregions of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus viminalis – Eucalyptus pauciflora* subsp. *pauciflora / Microlaena stipoides – Themeda australis – Poa labillardierei – Glycine clandestina – Dichondra repens – Gonocarpus tetragynus*

Number of samples:	52
Richness [mean (±SD)]:	40 (9)
Slope (degrees):	(0) 2–10 (18)
Altitude (m asl):	(585) 729–950 (1125)
Ave. Annual Rainfall (mm):	(677) 820–901 (1006)
Temp. Annual Range (°C):	(23.5) 24.5–25.6 (26.2)

Vegetation Description: Community p220 is a tall grassy woodland dominated by *Eucalyptus pauciflora* subsp. *pauciflora* and *Eucalyptus viminalis*, occasionally with *Eucalyptus radiata* subsp. *radiata.* The shrub layer is sparse or absent, with occasional occurrences of *Acacia melanoxylon*, *Rubus parvifolius* and low shrubs such as *Hibbertia obtusifolia* and *Bossiaea buxifolia.* The groundlayer is dense and dominated by grasses such as *Microlaena stipoides*, *Themeda australis*, *Poa labillardierei*, *Elymus scaber* and *Poa meionectes*, with forbs including *Glycine clandestina*, *Dichondra repens*, *Gonocarpus tetragynus*, *Hypericum gramineum*, *Hydrocotyle laxiflora*, *Acaena novae-zelandiae* and *Desmodium varians.*

This community occurs primarily on granitic soils on flat to gently undulating terrain east of the Great Dividing Range from Braidwood south to Bombala area, and westward to Tinderry NR. Along drainage lines this community may grade into the floristically similar Community p520 [*Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion*].

Characteristic Species:

Species	**C/A**	**Freq**	**C/A O**	**FreqO**	**Fid**
Acacia melanoxylon	1	50	1	13	P
Acaena novae-zelandiae	2	63	1	27	P
Acrotriche serrulata	1	40	1	11	P
Ajuga australis	2	31	1	7	P
Austrostipa rudis	2	15	1	3	P
Bossiaea buxifolia	2	46	1	6	P
Carex spp.	2	13	1	2	P
Cymbonotus lawsonianus	1	17	1	5	P
Cynoglossum australe	1	15	1	4	P
Desmodium gunnii	2	27	2	1	P
Desmodium varians	2	42	1	12	P
Dianella longifolia	1	31	1	2	P
Dichelachne inaequiglumis	2	33	2	6	P
Dichondra repens	2	77	2	20	P
Einadia nutans	2	17	1	4	P

Elymus scaber	1	48	1	21	P
Eucalyptus pauciflora subsp *pauciflora*	3	79	3	20	P
Eucalyptus radiata subsp. *radiata*	3	27	3	11	P
Eucalyptus stellulata	1	15	2	3	P
Eucalyptus viminalis	3	85	3	12	P
Euchiton japonicus	2	33	1	15	P
Geranium solanderi	2	40	1	19	P
Glycine clandestina	2	77	1	29	P
Gonocarpus tetragynus	2	73	2	47	P
Hovea heterophylla	1	23	1	4	P
Hovea linearis	2	33	1	13	P
Hydrocotyle laxiflora	2	60	2	29	P
Hypericum gramineum	1	67	1	25	P
Lomandra longifolia	2	63	2	42	P
Lomandra multiflora	1	44	1	18	P
Microlaena stipoides	2	88	2	33	P
Oxalis spp.	2	21	1	3	P
Panicum effusum	1	13	1	3	P
Poa labillardierei	3	62	2	9	P
Poa meionectes	2	52	2	16	P
Pteridium esculentum	2	52	2	27	P
Pultenaea subspicata	2	13	2	2	P
Rubus parvifolius	2	52	1	11	P
Rytidosperma laeve	2	19	2	4	P
Rytidosperma pilosum	2	29	2	9	P
Scleranthus biflorus	1	40	1	9	P
Senecio prenanthoides	2	52	1	19	P
Solenogyne gunnii	1	15	1	5	P
Themeda australis	2	79	2	20	P
Veronica calycina	2	44	1	16	P
Veronica plebeia	1	25	1	6	P
Viola betonicifolia	2	48	1	27	P
Wahlenbergia spp.	1	17	1	5	P
Hibbertia obtusifolia	2	50	1	34	C
Poa sieberiana	3	40	2	48	C

Threatened communities: This community is part of the TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: This community is largely equivalent to GWp220 [*Southern Tableland Flats Forest*] (Tozer *et al.* 2010).

Frequently occurring weeds: Remnants of this community are generally restricted to freehold grazing land. The most frequently encountered weeds are therefore those that are typical of other grassy woodlands in the South Eastern Highlands bioregion, including *Acetosella vulgaris* (0.37), *Cirsium vulgare* (0.27), *Holcus* lanatus (0.25), *Hypochaeris radicata* (0.92), and *Rosa rubiginosa* (0.27).

Threats: This formerly widespread community has historically been the target of extensive clearing for pastoral development. The community is now highly fragmented, generally only existing in small remnants or as secondary grassland. Remaining examples are subject to grazing pressures, weed invasion, firewood collection and.occasional small-scale clearing. Canopy dieback is a significant problem across much of the range of this community.

Reservation status: Likely to be poorly reserved. Examples of this community are found in Badja Swamps NR, Coolumbooka NR, Deua NP, Monga SCA and Tinderry NR.

Extent of clearing: This community has been widely cleared across its range primarily for pastoral development.

Reference: Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Plate p220: Community p220 beside Araluen Road near Reidsdale, with *Eucalyptus viminalis* and *Acacia melanoxylon* over a grassy groundcover dominated by *Poa labillardierei* var. *labillardierei.*

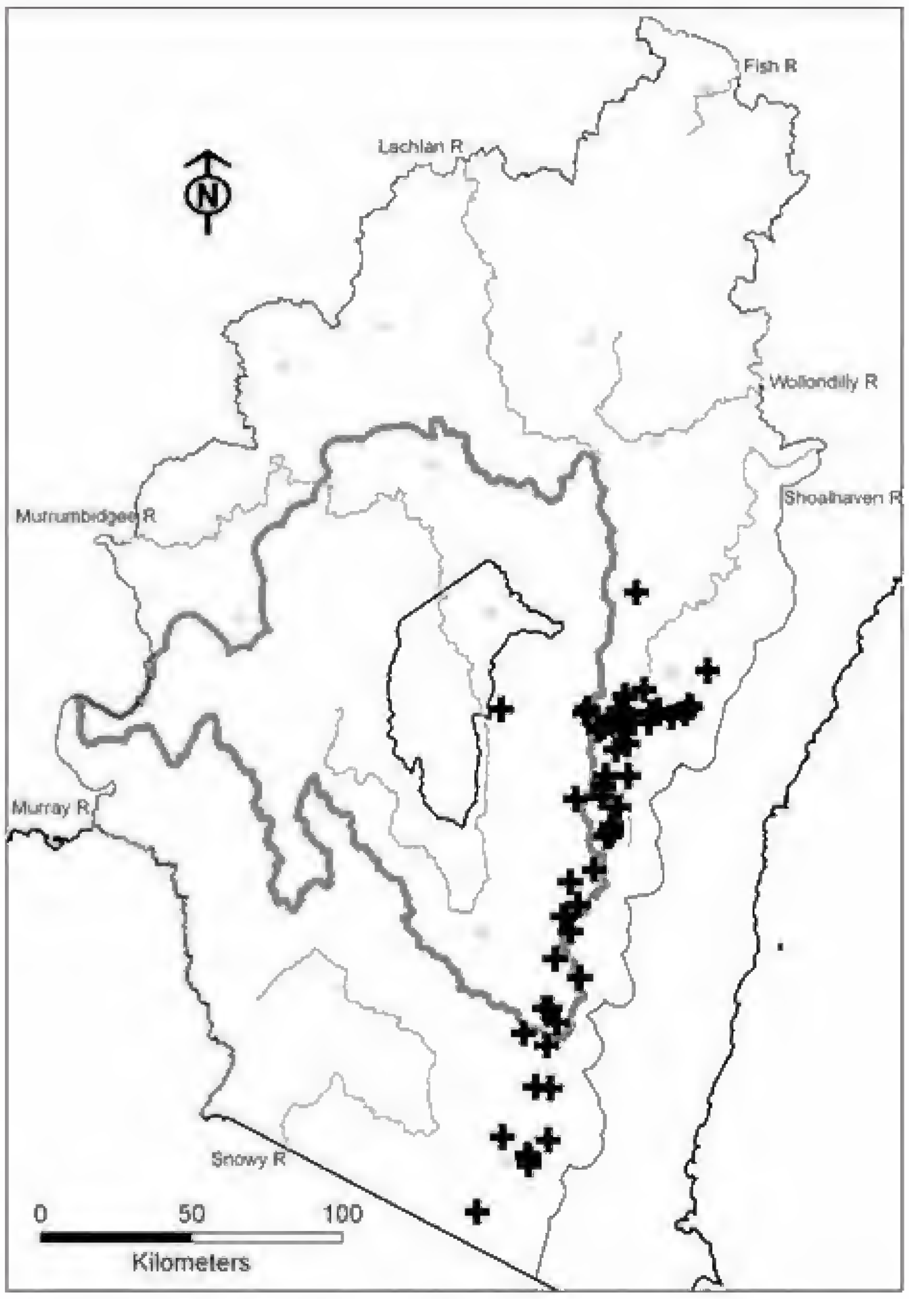

Fig. p220: Distribution of field samples assigned to this community.

p520: Ribbon Gum very tall woodland on alluvial soils along drainage lines of the eastern South Eastern Highlands bioregion

Scientific Name: *Eucalyptus viminalis* ± *Eucalyptus stellulata* – *Eucalyptus pauciflora* subsp. *pauciflora* / *Microlaena stipoides* – *Poa labillardierei* – *Dichondra repens* – *Acaena novae-zelandiae*

Number of samples:	42
Richness [mean (±SD)]:	33 (11)
Slope (degrees):	(0) 3–8 (19)
Altitude (m asl):	(551) 641–860 (1140)
Ave. Annual Rainfall (mm):	(639) 702–856 (968)
Temp. Annual Range (°C):	(23.7) 24.8–26.1 (26.5)

Vegetation Description: Community p520 is a very tall woodland to open forest characterised by *Eucalyptus viminalis*, sometimes with *Eucalyptus stellulata*, *Eucalyptus pauciflora* subsp. *pauciflora* or *Eucalyptus rubida*. Occasionally, *Eucalyptus aggregata* may be present. The shrub layer is sparse or absent, with infrequent groves of *Acacia melanoxylon*, *Acacia mearnsii*, *Lomatia myricoides* or *Leptospermum myrtifolium*. The groundlayer is dense and dominated by grasses such as *Microlaena stipoides*, *Poa labillardierei* and *Echinopogon ovatus*, with forbs including *Acaena novae-zelandiae*, *Dichondra repens*, *Hydrocotyle laxiflora*, *Stellaria pungens* and *Geranium solanderi*.

This community is distributed on alluvial flats across eastern parts of the South Eastern Highlands bioregion, from the Abercrombie River in the north to east of the Bredbo – Cooma area. Although unsampled further west, it is likely to occur in sandy lenses and creek flats along the Murrumbidgee River corridor in the ACT. It generally occurs on creek flats and coarse sandy alluvial soils along drainage channels. Away from the riparian zone, it commonly grades into Community p220 [*Ribbon Gum – Snow Gum tableland flats tall grassy woodland primarily on granitoids in the Kybean – Gourock and Monaro subregions of the South Eastern Highlands bioregion*] or, in steeper country, numerous dry sclerophyll forest types.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acacia mearnsii	3	19	2	3	P
Acaena novae-zelandiae	2	79	1	27	P
Carex appressa	1	45	1	6	P
Carex inversa	1	29	1	8	P
Desmodium varians	2	36	1	12	P
Dichondra repens	2	83	2	20	P
Echinopogon ovatus	2	45	1	10	P
Einadia nutans	1	24	1	4	P
Eucalyptus rubida	2	26	3	9	P
Eucalyptus stellulata	3	38	2	3	P
Eucalyptus viminalis	3	62	3	12	P
Geranium solanderi	2	52	1	19	P
Glycine clandestina	1	45	1	29	C
Glycine tabacina	2	21	1	3	P
Hydrocotyle laxiflora	2	62	2	29	P
Lomandra longifolia	2	45	2	42	C
Microlaena stipoides	3	95	2	33	P
Oreomyrrhis eriopoda	2	45	1	13	P
Oxalis perennans	2	36	1	13	P
Poa labillardierei	3	69	2	9	P
Poranthera microphylla	1	48	1	27	C
Rubus parvifolius	2	36	1	11	P
Rumex brownii	1	48	1	9	P
Rytidosperma racemosum	2	43	2	10	P
Solenogyne gunnii	1	19	1	5	P
Stellaria pungens	2	57	2	31	P
Veronica plebeia	1	26	1	6	P
Viola betonicifolia	1	48	1	27	C

Plate p520: Community p520, Doughboy TSR (near plot MAN021A), with *Eucalyptus viminalis* and *Eucalyptus stellulata* over scattered *Acacia mearnsii* and a diverse grass/forb groundcover.

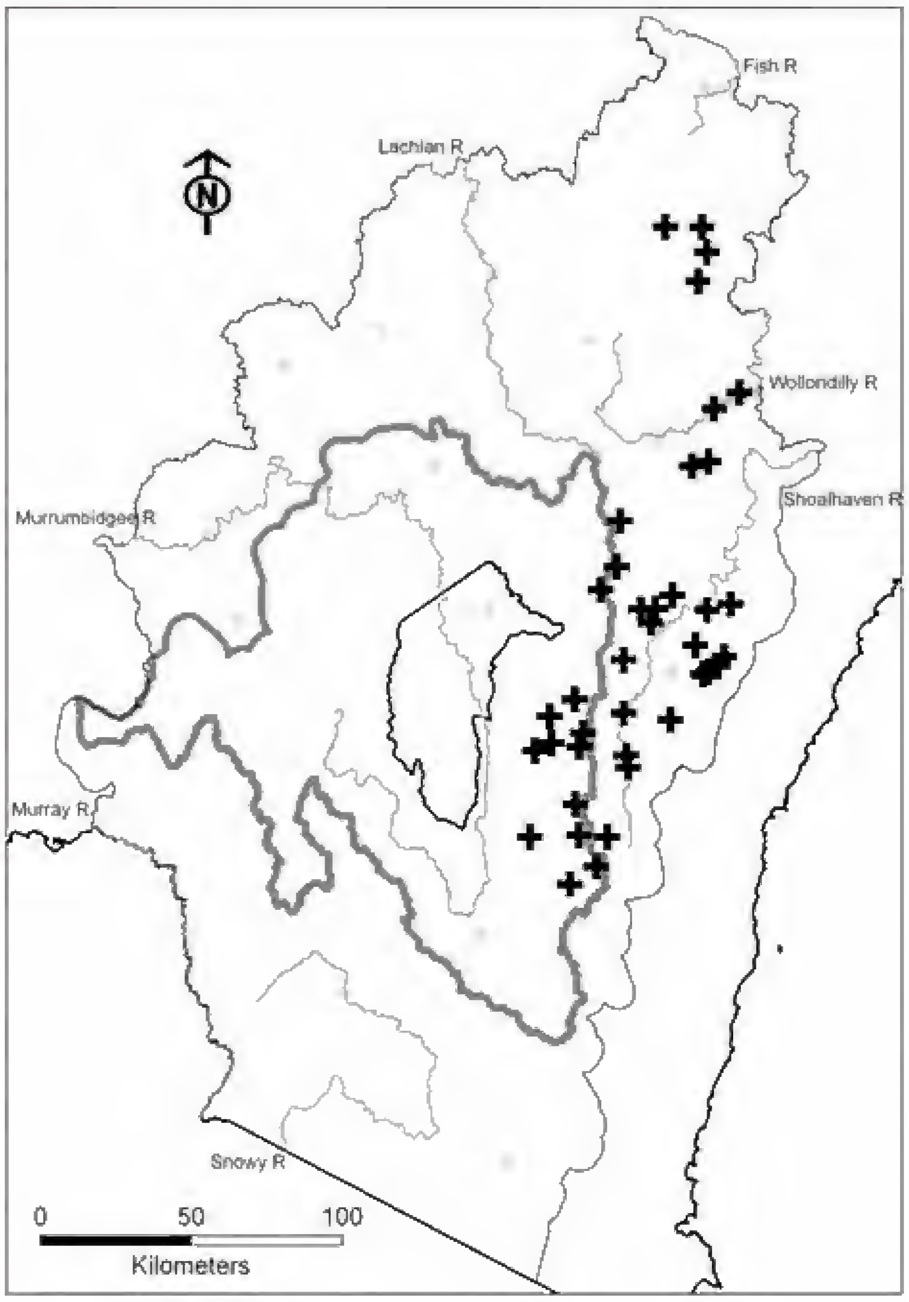

Fig. p520: Distribution of field samples assigned to this community.

Threatened communities: This community is part of the TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: This community is similar to GWp520 [*Tableland Swamp Flats Forest*] (Tozer *et al.* 2010), with the community described in this study containing a higher frequency of *Eucalyptus stellulata* and *Eucalyptus rubida*, and less *Eucalyptus pauciflora* ssp. *pauciflora.*

Frequently occurring weeds: Although examples of this community are found on public land, the majority of remnants occur on freehold grazing land. As with most grassy woodlands on this tenure, weeds are a major component of the remnant vegetation, the most common of which are *Acetosella vulgaris* (0.55), *Cirsium vulgare* (0.74), *Holcus lanatus* (0.5), *Hypochaeris radicata* (0.79), *Plantago lanceolata* (0.47), *Rosa rubiginosa* (0.42), *Rubus ulmifolius* (0.37) and *Trifolium repens* (0.32).

Threats: Community p520 was extensively cleared because it occupied relatively fertile alluvial soils suitable for agriculture. Examples on sandy alluvial lenses may be subject to less clearing pressure. Remnants are generally small and isolated, subject to ongoing degradation from domestic stock grazing, weed invasion, firewood collection and small-scale clearing.

Reservation status: Unknown, although examples are found in drainage areas in Abercrombie River NP, Badja Swamps NR, Blue Mountains NP, Deua NP, Gourock NP, Kanangra-Boyd NP, Macanally SCA, Monga SCA, Mount Dowling NR, Quidong NR, Tallaganda NP, Tinderry NR, Wiarborough NR and Yanununbeyan SCA.

Extent of clearing: This community has been widely cleared across its range primarily for pastoral development.

Reference: Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

u78: Snow Gum grassy mid-high woodland of the South Eastern Highlands bioregion

Scientific Name: *Eucalyptus pauciflora* subsp. *pauciflora* ± *Eucalyptus bridgesiana / Astroloma humifusum – Hibbertia obtusifolia / Themeda australis – Microlaena stipoides – Poa sieberiana – Chrysocephalum apiculatum*

Number of samples:	27
Richness [mean (±SD)]:	31 (8)
Slope (degrees):	(0) 1–4 (8)
Altitude (m asl):	(584) 683–792 (940)
Ave. Annual Rainfall (mm):	(641) 699–798 (874)
Temp. Annual Range (°C):	(24.3) 25.6–26.2 (26.8)

Vegetation Description: Community u78 is a mid-high grassy woodland dominated by *Eucalyptus pauciflora* subsp. *pauciflora* occasionally with *Eucalyptus bridgesiana*. The shrub layer is sparse or absent, with infrequent occurrences of low shrubs such as *Pimelea curviflora*, *Astroloma humifusum*, and *Hibbertia obtusifolia* at low abundance. The groundlayer is dense and dominated by grasses such as *Themeda australis*, *Microlaena stipoides*, *Poa sieberiana*, *Elymus scaber*, *Aristida ramosa* and *Rytidosperma racemosum.* Forb species include *Chrysocephalum apiculatum*, *Gonocarpus tetragynus*, *Hypericum gramineum*, *Lomandra filiformis* subsp. *coriacea*, *Acaena echinata* and *Asperula conferta.* Heavily grazed remnants may be dominated by less-palatable species such as *Aristida ramosa*, *Rytidosperma* spp. and *Bothriochloa macra*.

Community u78 occurs on flat to undulating clay landscapes from the Crookwell area south to the Braidwood area. It is mostly found on private grazing land and as such has been highly modified and cleared across its range. It grades into tableland grassland communities such as Community r7 [*Themeda australis – Rytidosperma* sp. *– Poa sieberiana*

Plate u78: Community u78 with mature and regenerating *Eucalyptus pauciflora* ssp. *pauciflora*, and a mix of grasses and forbs.

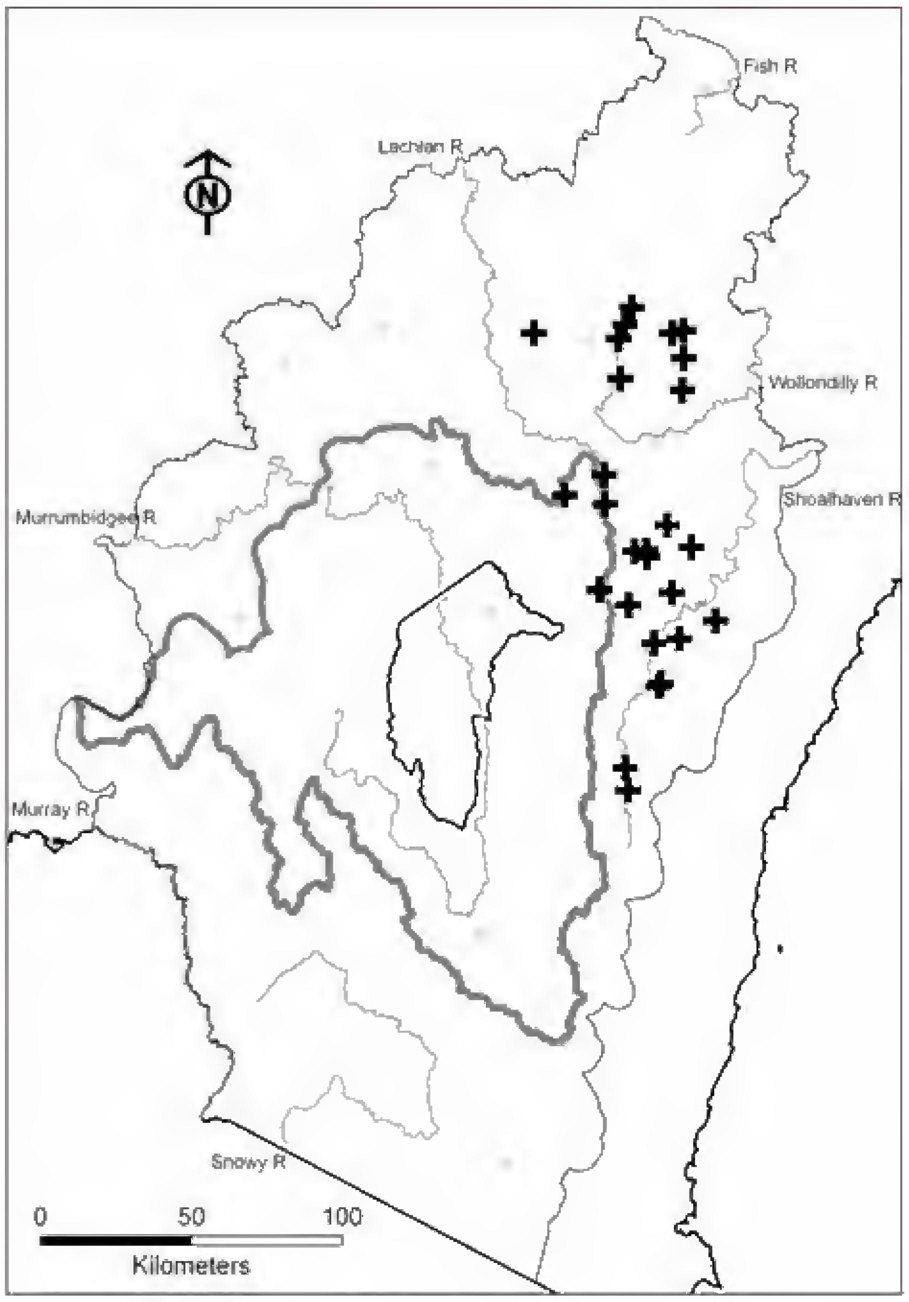

Fig. u78: Distribution of field samples assigned to this community.

moist tussock grassland of the South Eastern Highlands bioregion], which can also contain scattered occurrences of *Eucalyptus pauciflora* subsp. *pauciflora* at low abundance.

Characteristic Species:

Species	C/A	Freq	C/A O	FreqO	Fid
Acaena echinata	1	52	1	9	P
Aristida ramosa	2	48	2	5	P
Asperula conferta	1	44	1	10	P
Astroloma humifusum	1	33	1	5	P
Bothriochloa macra	1	26	1	3	P
Calocephalus citreus	2	22	1	<1	P
Carex inversa	2	37	1	8	P
Chrysocephalum apiculatum	2	67	1	6	P
Dichelachne micrantha	1	33	1	10	P
Einadia nutans	1	26	1	4	P
Elymus scaber	1	59	1	21	P
Eryngium ovinum	1	22	1	<1	P
Eucalyptus bridgesiana	2	26	3	7	P
Eucalyptus pauciflora subsp. *pauciflora*	3	89	3	20	P
Hypericum gramineum	2	59	1	25	P
Lomandra filiformis subsp. *coriacea*	2	59	2	18	P
Microlaena stipoides	3	96	2	34	P
Oxalis exilis	2	22	1	5	P
Panicum effusum	2	41	1	3	P
Pimelea curviflora	2	37	1	6	P
Plantago varia	2	37	1	11	P
Poa labillardierei	2	37	2	10	P
Rytidosperma laeve	2	26	2	4	P
Rytidosperma pilosum	2	30	2	9	P
Rytidosperma racemosum	2	44	2	10	P
Scleranthus biflorus	2	37	1	10	P
Solenogyne gunnii	1	22	1	5	P
Themeda australis	3	100	2	20	P
Tricoryne elatior	2	41	1	4	P
Wahlenbergia communis	1	26	1	5	P
Wahlenbergia luteola	2	26	1	1	P
Gonocarpus tetragynus	2	63	2	48	C
Hydrocotyle laxiflora	2	44	2	30	C
Poa sieberiana	3	74	2	48	C

Threatened communities: This community is part of the TSC Act 1995 – *Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes bioregions.*

Equivalent vegetation types: Given the lack of adequate previous woodland classifications, there are no clear equivalent communities. There are some affinities with p22 [*Frost Hollow Grassy Woodland*] and p24 [*Tableland Grassy Box-Gum Woodland*] as described by Tozer *et al.* (2010).

Frequently occurring weeds: This community is generally confined to private properties where grazing of domestic stock is the primary landuse. Typcial weeds are those associated with this landuse and include *Acetosella vulgaris* (0.62), *Centaurium erythraea* (0.23), *Cirsium vulgare* (0.23), *Crataegus monogyna* (0.23), *Hypochaeris radicata* (0.85), *Plantago lanceolata* (0.58) and *Rosa rubiginosa* (0.46). Where pasture improvement has occurred *Dactylis glomerata* (0.23), *Holcus lanatus* (0.23) and *Paspalum dilatatum* (0.23) are more common.

Threats: This community was extensively cleared because it occurred on land well-suited to agricultural development. The community is now highly fragmented and remnants are subject to grazing pressures, weed invasion, firewood collection, and occasionally small-scale clearing.

Reservation status: This community is poorly reserved. Examples occur in Oakdale NR.

Extent of clearing: Clearing of this vegetation type is known to be high across its known range due to pastoral development.

Reference: Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Formation: Grasslands

Class: Temperate Montane Grasslands

Note: Grasslands were classified through a separate analysis (Rehwinkel unpub.) to that of the woody and alpine communities, and as such CA/O (cover/abundance of taxa recorded in other communities), Freq O (frequency of taxa recorded in other communities) and Fid (fidelity) measures are not presented.

r1: Sub-montane moist tussock grassland of the South Eastern Highlands bioregion

Scientific Name: *Poa sieberiana – Themeda australis – Ranunculus lappulaceus – Coronidium* **sp. 'Alps'** – *Plantago gaudichaudii – Brachyscome scapigera*

Number of samples:	22
Richness [mean (±SD)]:	20 (5)
Slope (degrees):	(0) 2–5 (10)
Altitude (m asl):	(717) 919–1129 (1171)
Ave. Annual Rainfall (mm):	(683) 725–800 (897)
Temp. Annual Range (°C):	(25.0) 25.4–26.9 (27.7)

Vegetation Description: Community r1 is a dense moist tussock grassland dominated by *Poa sieberiana* and/or *Themeda australis* in the upper stratum with a variety of forbs in the inter-tussock spaces, including *Brachyscome scapigera*, *Asperula* spp. (*Asperula conferta* or *Asperula scoparia*), *Coronidium* **sp. 'Alps'**, *Plantago antarctica*, *Hydrocotyle algida*, *Ranunculus lappaceus*, *Geranium antrorsum* and *Leptorhynchos squamatus.* Other grasses are present including *Rytidosperma* spp., *Elymus scaber* and *Hemarthria uncinata.* A variety of rushes *Juncus* spp. and sedges *Carex* spp. may also be present. Isolated or scattered trees may occur including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus dalrympleana, Eucalyptus ovata* or *Acacia melanoxylon.* There may be isolated shrubs or patches of shrubs including *Hakea microcarpa*, *Discaria pubescens*, *Banksia marginata*, *Bossiaea riparia*, *Bursaria spinosa* and *Mirbelia oxylobioides.* Trees and shrubs increase in density at ecotones with adjacent woodland and forest communities. Relatively undisturbed sites may have a variety of uncommon grassland forbs, including *Prasophyllum wilkinsoniorum*, *Diplarrena moraea* and *Thysanotus tuberosus.*

This community is found on a variety of substrates but most commonly on colluvium or alluvium on footslopes and flats. It also occurs on basalt and granite lithologies and on midslopes and plateaux. Poor soil drainage, seasonal waterlogging and severe frosts drive the distribution of this community, as they restrict the establishment of woody species. Community r1 occurs in the southern ACT (Namadgi NP) and the adjacent Yaouk area in NSW. Elsewhere in NSW, it occurs near Delegate, Nunnock Swamp (South East Forests NP), Kydra River and the upper headwaters of the Shoalhaven River (Deua NP). Degraded sites (i.e. lacking some of the main species that define this community) may be difficult to distinguish from degraded sites of Community r2 [*Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion*] or Community r7 [*Themeda australis – Rytidosperma* sp. – *Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq
Acaena novae-zelandiae	1	45
Acaena ovina	1	27
Asperula spp.	1	95

Brachyscome scapigera	1	59
Carex spp.	1	77
Chrysocephalum apiculatum	1	27
Coronidium sp. 'Alps'	1	64
Craspedia spp.	1	45
Cynoglossum suaveolens	1	27
Elymus scaber	1	36
Epilobium spp.	1	41
Euchiton spp.	1	23
Geranium antrorsum	1	55
Geranium spp.	1	59
Hemarthria uncinata	1	23
Hydrocotyle laxiflora	1	41
Juncus spp.	1	73
Leptorhynchos squamatus	1	55
Lomandra longifolia	1	32
Luzula spp.	1	23
Microlaena stipoides	1	27
Oreomyrrhis eriopoda	1	32
Oxalis perennans	1	36
Plantago antarctica	1	45
Plantago gaudichaudii	1	64
Poa labillardierei	1	23
Poa sieberiana	4	100
Ranunculus lappaceus	1	68
Rumex brownii	1	73
Rytidosperma spp.	1	59
Scleranthus biflorus	1	45
Solenogyne gunnii	1	36
Stylidium graminifolium sens. lat.	1	36
Themeda australis	3	100
Veronica gracilis	1	41
Viola betonicifolia	1	32
Wahlenbergia spp.	1	27

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory*; NC Act 1980 – *Natural Temperate Grassland.*

Equivalent vegetation types: This community is equivalent to Group 1 (Rehwinkel unpub.).

Frequently occurring weeds: The naturally open nature of this community made it highly attractive to pastoral management. Common weeds are those typical of other grassy ecosystems of the region, including *Anthoxanthum odoratum*, *Hypochaeris radicata* and *Acetosella vulgaris.*

Threats: This community has been extensively cleared and remnants are subject to continued small-scale clearing, weed invasion and grazing pressures.

Reservation status: Poorly reserved. Occurs in Deua NP, Namadgi NP, South East Forests NP and Yaouk NR. Also on Nature Conservation Trust covenanted lands in the upper Shoalhaven River area.

Extent of clearing: Unknown, although throughout its range only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

Plate r1: *Poa sieberiana* and *Themeda australis* dominate this forb-rich example of Community r1 in the Jerrabatgulla Creek area south of Braidwood.

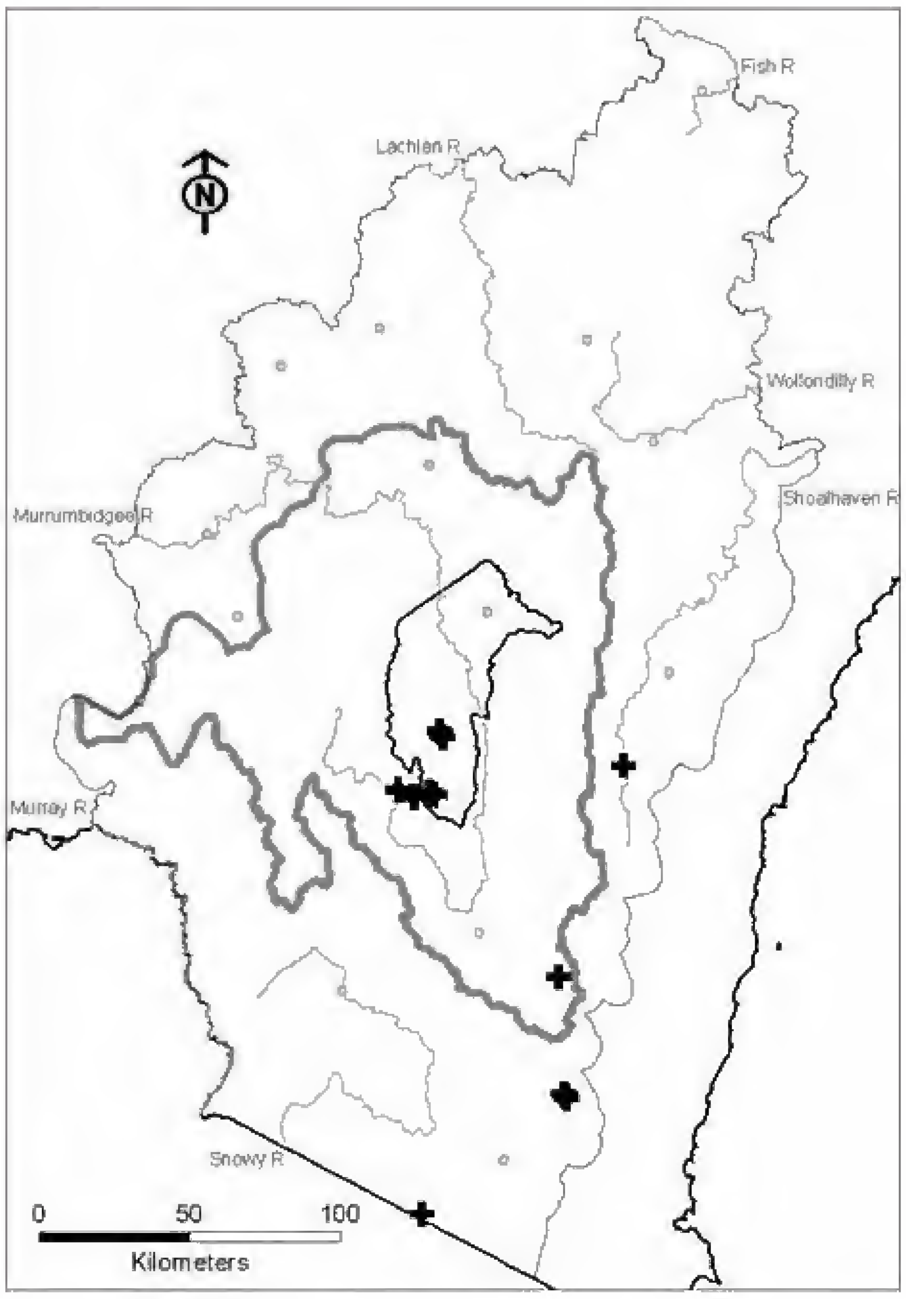

Fig. r1: Distribution of field samples assigned to this community.

r2: *Poa labillardierei – Themeda australis – Juncus sp.* wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion

Scientific Name: *Poa labillardierei – Themeda australis – Juncus* spp.

Number of samples:	45
Richness [mean (±SD)]:	17 (3)
Slope (degrees):	(0) 2–6 (15)
Altitude (m asl):	(562) 608–857 (1313)
Ave. Annual Rainfall (mm):	(526) 649–731 (877)
Temp. Annual Range (°C):	(24.9) 26.5–27.7 (28.8)

Vegetation Description: Community r2 is a tall, dense or mid-dense wet tussock grassland dominated by *Poa labillardierei* usually with *Themeda australis*, the sedge *Carex appressa* and rush *Juncus* spp. in the upper stratum and a variety of grasses and forbs in the intertussock spaces, including *Microlaena stipoides*, *Rytidosperma* spp., *Elymus scaber*, *Acaena ovina*, *Asperula* spp. (*Asperula conferta* or *Asperula scoparia*), *Euphrasia* spp., *Coronidium* sp. 'Alps' and *Hemarthria uncinata.* Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus viminalis*, *Eucalyptus rubida*, *Eucalyptus stellulata*, *Eucalyptus aggregata, Eucalyptus bridgesiana*, *Acacia dealbata*, *Acacia mearnsii* or *Acacia melanoxylon*. Isolated shrubs or patches of shrubs may also occur including *Kunzea parvifolia*, *Melaleuca parvistaminea*, *Astroloma humifusum*, *Einadia nutans* and *Hakea microcarpa*. Trees and shrubs increase in density where this community merges into the adjacent woodland communities. Relatively undisturbed sites may have a variety of uncommon grassland forbs including *Craspedia* spp., *Geranium antrorsum*, *Calocephalus citreus*, *Ranunculus lappaceus* and *Brachyscome decipiens.*

Community r2 is found on colluvium or alluvium and on drainage lines in footslopes and particularly on the broad flats associated with creeks and rivers. Poor soil drainage associated with frequent seasonal waterlogging and, to a lesser degree winter frosts, drive the distribution of this community as they restrict the establishment of woody taxa. It is distributed widely across the region wherever suitable habitat exists. Degraded sites (i.e. lacking some of the main diagnostic taxa) may be confused with degraded examples of Community r3 [*Rytidosperma sp. – Themeda australis – Juncus sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion*] or Community r7 [*Themeda australis – Rytidosperma* sp. *– Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq
Acaena novae-zelandiae	1	25
Acaena ovina	1	44
Aristida spp.	1	21
Asperula spp.	1	44
Carex appressa	1	42
Carex spp.	1	38
Coronidium sp. 'Alps'	1	31
Craspedia spp.	1	21
Elymus scaber	1	44
Epilobium spp.	1	38
Eragrostis spp.	1	27
Euchiton spp.	1	40
Geranium spp.	1	33
Hemarthria uncinata	1	23
Hydrocotyle algida	1	29
Hypericum gramineum	1	25
Juncus spp.	2	81
Lachnagrostis spp.	1	27

Plate r2: Tall tussocks of *Poa labillardierei* dominate this example of Community site on the Molonglo River, while grasses and forbs characteristic of wetter areas occupy the inter-tussock spaces.

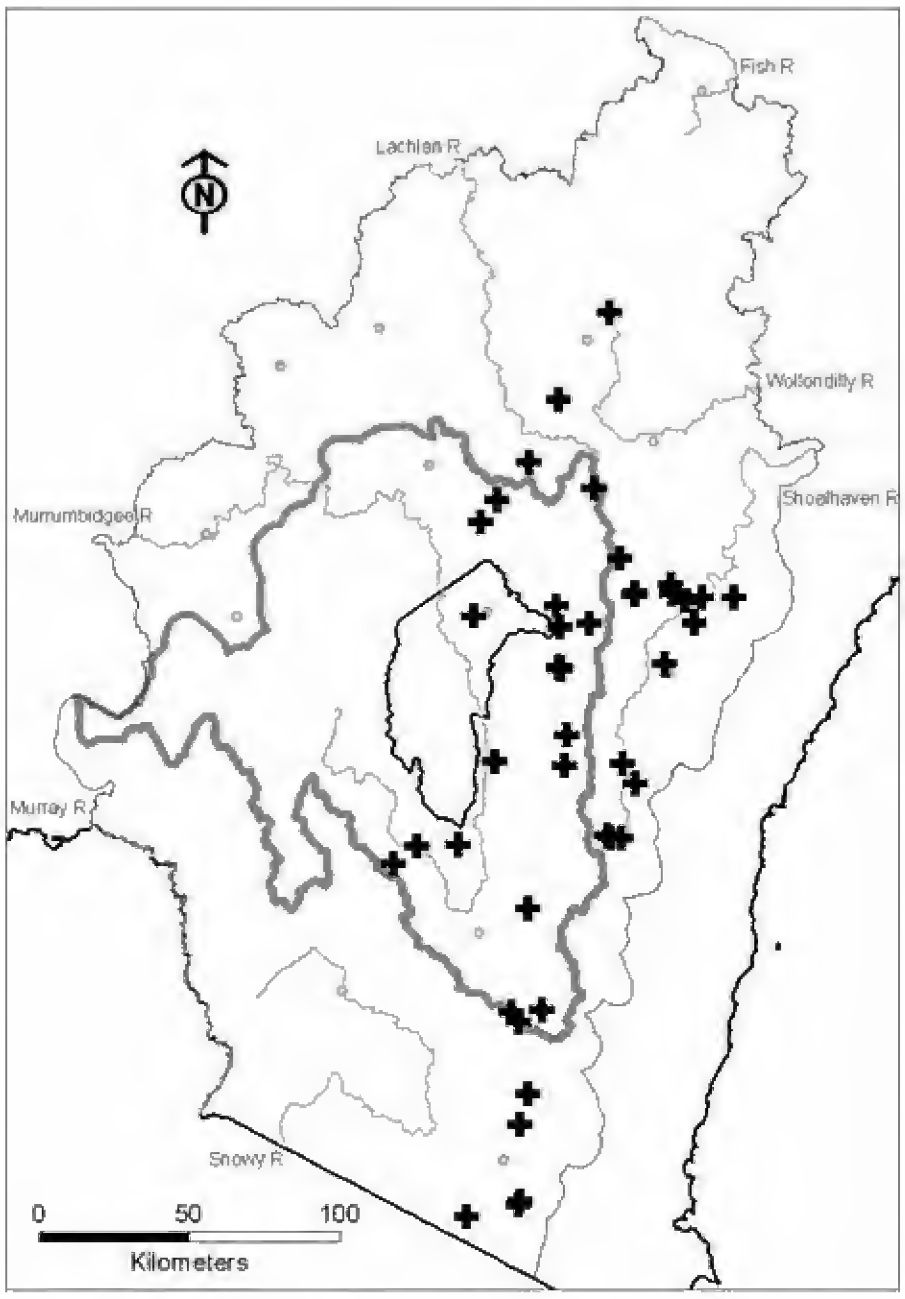

Fig. r2: Distribution of field samples assigned to this community.

Leptorhynchos squamatus	1	23
Microlaena stipoides	1	42
Oxalis perennans	1	31
Panicum effusum	1	23
Persicaria prostrata	1	21
Poa labillardierei	5	94
Poa meionectes	1	25
Rumex brownii	1	38
Rytidosperma spp.	1	44
Schoenus apogon	1	21
Scleranthus biflorus	1	31
Solenogyne gunnii	1	23
Themeda australis	3	67

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory*; NC Act 1980 – *Natural Temperate Grassland.*

Equivalent vegetation types: Community 8 (Benson 1994); Group 2 (Rehwinkel unpub.); Draft VCA 635 [*Tall wet tussock grassland on footslopes, depressions and flats of the South Eastern Highlands bioregion*] (Benson in prep.)

Frequently occurring weeds: Because this grassland community occurs on sites of high soil fertility, it has a long history of grazing, clearing and exotic pasture introduction. The most frequently recorded species within this community are *Hypochaeris radicata*, *Acetosella vulgaris*, *Phalaris aquatica*, *Holcus lanatus*, *Bromus* spp., *Vulpia* spp., *Festuca arundinacea* and *Paspalum dilatatum,* which are all typical of heavily grazed sites on fertile soil.

Threats: This community has been extensively cleared and remnants are subject to nutrient run-on from adjacent fertilised crops and pastures, small-scale clearing, weed invasion and grazing pressures.

Reservation status: Poorly reserved. Occurs in Deua NP, Tinderry NR and Yaouk NR, with a very minor occurrence at Turallo NR. It is also found on Nature Conservation Trust covenanted land in the upper Shoalhaven River, and at the Scottsdale Bush Heritage Reserve near Cooma.

Extent of clearing: Clearing figures are unavailable for grassland communities. Throughout its range only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Benson, J.S. (1994) The native grasslands of the Monaro region: southern tablelands of New South Wales. *Cunninghamia* 3: 609–650; Benson, J.S. (in prep.) New South Wales vegetation classification and assessment: Part 4. Plant communities of the west South Eastern Highlands and Australian Alps bioregions. Botanic Gardens Trust, Sydney; Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

r3: *Rytidosperma sp. – Themeda australis – Juncus sp.* tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion

Scientific Name: *Rytidosperma* spp. – *Themeda australis* – *Juncus* **spp**. – *Schoenus apogon* – *Haloragis heterophylla* – *Lachnagrostis* **spp**.

Number of samples:	15
Richness [mean (±SD)]:	22 (8)
Slope (degrees):	(0) 0–2 (5)
Altitude (m asl):	(586) 644–713 (860)
Ave. Annual Rainfall (mm):	(593) 666–746 (984)
Temp. Annual Range (°C):	(27.0) 27.9–28.5 (29.4)

Vegetation Description: Community r3 is a dense to mid-dense, low to mid-high tussock grassland dominated by wallaby-grasses (*Rytidosperma* spp.) and/or *Themeda australis*, with rushes (*Juncus* spp.) in the upper stratum and a variety of smaller grasses, sedges and forbs in the lower stratum. Lower stratum species include *Lachnagrostis* spp., *Schoenus apogon*, *Haloragis heterophylla, Hydrocotyle algida*, *Carex appressa*, *Amphibromus* spp. and *Elymus scaber*. Isolated or scattered trees may be present, including *Eucalyptus ovata*, *Eucalyptus rubida* and *Eucalyptus pauciflora* subsp. *pauciflora*. Trees increase in density at ecotones with adjacent woodland or (rarely) forest communities. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Craspedia* spp., *Dichopogon fimbriatus*, *Montia australasica* and *Calotis anthemoides.*

This community is found most commonly on flats on or adjacent drainage lines or wetlands, and occasionally on footslope and midslope situations. Substrates are colluvium or alluvium derived from sedimentary or granite parent material. Poor soil drainage associated with frequent seasonal waterlogging and severe winter frosts drive the distribution of this community, as they restrict the establishment of woody taxa. This community occurs in the Bondo and Murrumbateman subregions of the South Eastern Highlands bioregion and the upper Shoalhaven valley. Degraded sites (i.e. lacking some of the main diagnostic taxa) may be confused with degraded examples of Community r2 [*Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion*], although Community r3 generally occurs on drier sites than those occupied by Community r2. Community r7 [*Themeda australis – Rytidosperma* sp. *– Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion*] is another grassland community with which Community r3 frequently co-occurs.

Characteristic Species:

Species	**C/A**	**Freq**
Acaena ovina	1	29
Amphibromus spp.	1	48
Asperula spp.	1	43
Austrostipa bigeniculata	1	24
Calotis anthemoides	1	24
Carex appressa	1	57
Carex spp.	1	57
Coronidium sp. 'Alps'	1	33
Craspedia spp.	1	33
Cynodon dactylon	1	33
Deyeuxia quadriseta	1	24
Dichelachne spp.	1	33
Dichopogon fimbriatus	1	29
Drosera peltata	1	48
Elymus scaber	1	62
Epilobium spp.	1	52
Eragrostis spp.	1	43
Euchiton spp.	2	90

Plate r3: Occupying a seasonally moist zone between the wetland and a dryer area occupied by Community r7, this moist Community r3 site adjacent to Rowes Lagoon is dominated by Themeda australis, *Rytidosperma* spp. and a suite of other moisture-loving grasses and forbs.

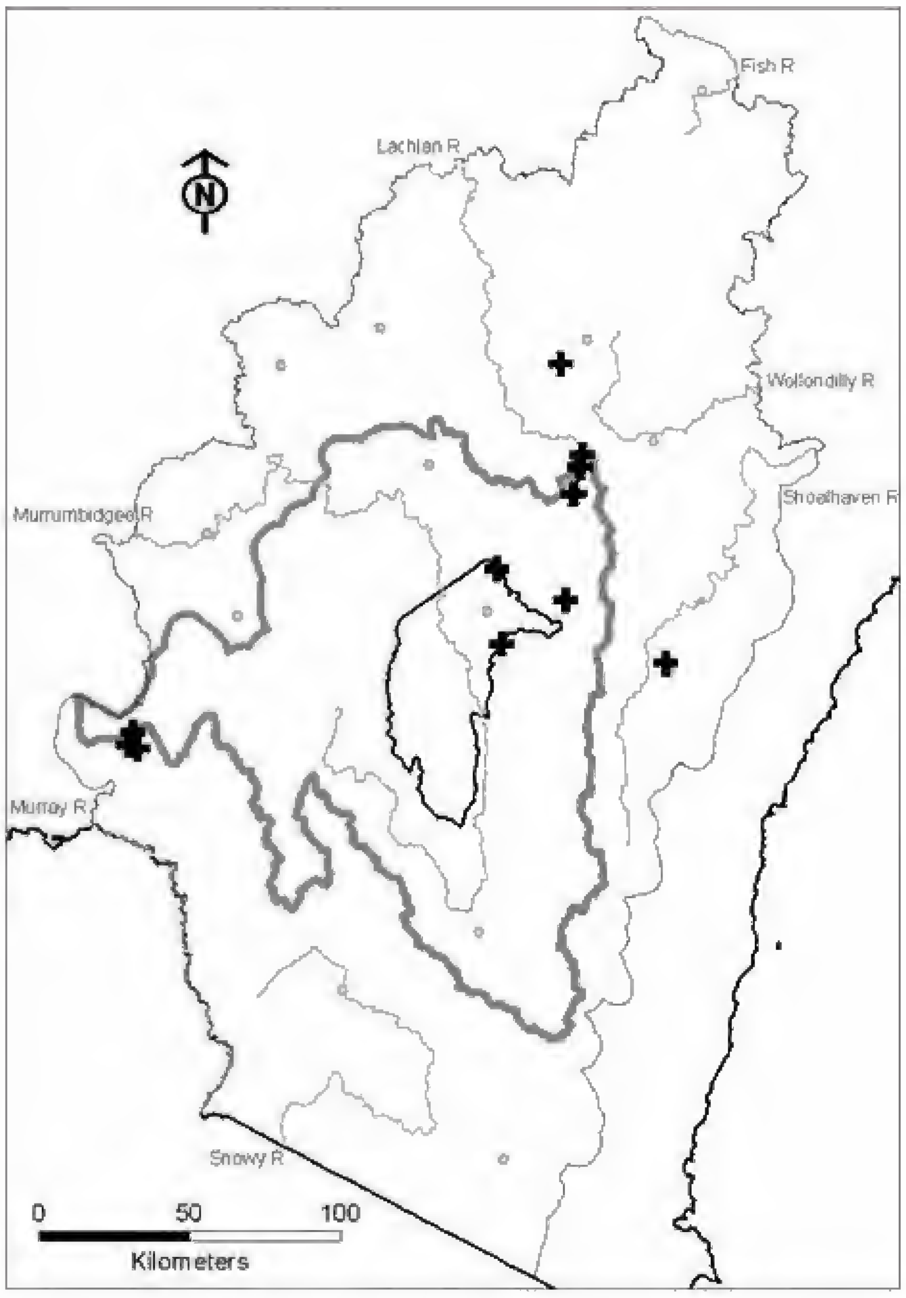

Fig. r3: Distribution of field samples assigned to this community.

Gonocarpus tetragynus	1	24
Haloragis heterophylla	2	81
Hemarthria uncinata	1	33
Hydrocotyle algida	2	62
Hypericum gramineum	1	48
Hypoxis spp.	1	33
Isotoma fluviatilis	1	33
Juncus spp.	3	95
Lachnagrostis spp.	2	67
Luzula spp.	1	43
Lythrum hyssopifolia	1	57
Microlaena stipoides	1	48
Microtis spp.	1	38
Montia australasica	1	29
Oxalis perennans	1	38
Persicaria prostrata	1	29
Poa labillardierei	1	38
Poa sieberiana	1	43
Rumex brownii	1	67
Rytidosperma spp.	4	100
Schoenus apogon	2	81
Themeda australis	3	67
Triptilodiscus pygmaeus	1	24
Wahlenbergia spp.	1	52
Wurmbea dioica	1	24

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory*; NC Act 1980 – *Natural Temperate Grassland.*

Equivalent vegetation types: Group 3 (Rehwinkel unpub.), Draft VCA 637 [*Wallaby Grass – Blown Grass – Rush moist tussock grassland of seasonally wet sites in the South Eastern Highlands bioregion*] (Benson in prep.).

Frequently occurring weeds: The weeds *Anthoxanthum odoratum*, *Hypochaeris radicata*, *Acetosella vulgaris*, *Holcus lanatus*, *Paspalum dilatatum*, *Festuca arundinacea*, *Vulpia* spp. and *Phalaris aquatica* were common in this community

Threats: This community has been extensively cleared and remnants are subject to small-scale clearing, weed invasion, grazing pressures, and nutrient run-on from adjacent fertilised crops and pastures.

Reservation status: Poorly reserved. There is a very minor occurrence at Turallo NR and at Mulligans Flat NR.

Extent of clearing: Unknown, although throughout its range, only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Benson, J.S. (in prep.) New South Wales vegetation classification and assessment: Part 4. Plant communities of the west South Eastern Highlands and Australian Alps bioregions. Botanic Gardens Trust, Sydney; Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

r4: Lacustrine grass-forbland of the South Eastern Highlands bioregion

Scientific Name: *Lachnagrostis* **spp.** – *Wilsonia rotundifolia* – *Carex bichenoviana* – – *Selliera radicans* – *Juncus* **spp.**

Number of samples:	5
Richness [mean (±SD)]:	10 (5)
Slope (degrees):	(0) 0–0 (0)
Altitude (m asl):	(709) 709–709 (709)
Ave. Annual Rainfall (mm):	(629) 637–650 (657)
Temp. Annual Range (°C):	(28.1) 28.1–28.2 (28.2)

Vegetation Description: Community r4 is a variable lake-margin and dry lake-bed vegetation type with structure and composition varying in response to lake wetting and drying cycles. Structure ranges from very open to dense, low to mid-high, forbland to tussock grassland, sometimes with patches of sedgeland. Dominant species include *Lachnagrostis* spp., *Carex bichenoviana* and *Juncus* spp. in the upper stratum, and a variety of forbs and shorter grasses in the lower stratum including *Wilsonia rotundifolia*, *Selliera radicans*, *Dichondra repens*, *Ranunculus diminutus*, *Cynodon dactylon*, *Chenopodium glaucum*, *Rytidosperma* spp., *Lythrum hyssopifolia*, *Panicum effusum* and *Centella asiatica*. During shallow inundation the forbs *Wilsonia rotundifolia*, *Selliera radicans* and *Ranunculus diminutus* may survive for extended periods, including their underground parts, re-emerging first during drying phases to create a dense forbland. *Wilsonia rotundifolia* and *Selliera radicans* are particularly prevalent in brackish lakes such as Lacke George and Lake Bathurst. Grasses (particularly *Lachnagrostis* spp.) and forbs characteristic of drier habitats re-colonise drying lake margins over time. Dry phases may last in excess of ten years, occasionally allowing establishment of eucalypt saplings.

The five samples used to define this community were from the bed and foreshores of Lake George. Community r4 is also known from similar broad lake beds of Lake Bathurst, the margins of Rowes Lagoon and some lakes of the Monaro. The beds of these tableland lakes are alluvial mud, silt and sand. The combined factors of seasonal waterlogging, cracking clays, extended dry periods and severe winds limit the establishment of woody taxa. The Lake Bathurst example is distinct in that it has isolated populations of *Dodonaea procumbens*, *Pelargonium* sp. Striatellum (G. W. Carr 10345), *Schoenus nitens*, *Rulingia prostrata* and the only NSW record of *Lawrencia spicata*. Rowes Lagoon is distinct in that it has an isolated population of *Rulingia prostrata* and several daisies including *Chrysocephalum apiculatum*, *Calocephalus citreus* and *Leptorhynchos squamatus*. This community may also form on some of the Monaro lakes when they are dry. Populations of *Pelargonium* sp. Striatellum (G. W. Carr 10345) have been recorded on at least two of the Monaro lakes belonging to this community.

At ecotones between drier sites, Community r4 may merge with Community r3 [*Rytidosperma sp. – Themeda australis – Juncus sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion*], which occurs above the shorelines of Rowes Lagoon and Breadalbane Lagoon. When indundated for extended periods, sites occupied by Community r4 are most likely to become Community L12 [*Freshwater sedge-herb marsh of shallow, commonly inundated wetlands of the eastern South Eastern Highlands bioregion*] or, when significantly deeper, Community L4 [*Freshwater sedge-herb marsh of deep semi-permanent and/or slightly saline wetlands of the eastern South Eastern Highlands bioregion*].

Plate r4: During long droughts, the dry lakebed of Lake George is occupied by Community r4, dominated by *Lachnagrostis filiformis* and *9*.

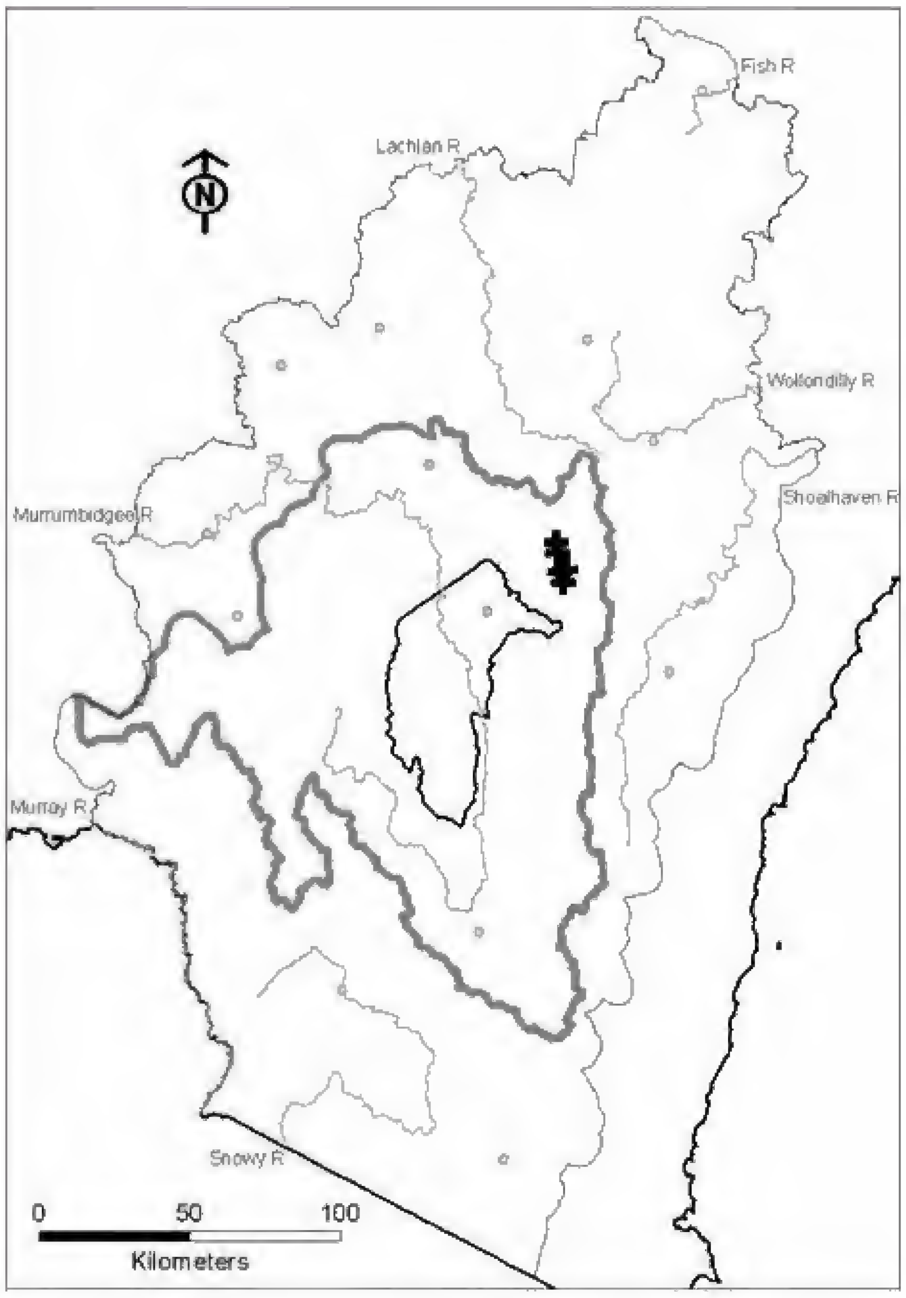

Fig. r4: Distribution of field samples assigned to this community.

Characteristic Species:

Species	C/A	Freq
Bothriochloa macra	1	20
Brachyscome graminea	1	20
Carex bichenoviana	3	80
Centella asiatica	1	20
Chenopodium glaucum	1	60
Chloris truncata	1	20
Convolvulus angustissimus	1	20
Cynodon dactylon	1	60
Dichondra repens	1	40
Epilobium spp.	1	40
Juncus spp.	2	60
Lachnagrostis spp.	4	100
Lythrum hyssopifolia	1	40
Panicum effusum	1	20
Pennisetum alopecuroides	1	20
Persicaria prostrata	1	20
Ranunculus diminutus	1	80
Rumex brownii	1	40
Rytidosperma spp.	1	40
Selliera radicans	2	80
Wilsonia rotundifolia	3	100

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory.*

Equivalent vegetation types: Identified by Rehwinkel (unpub.) as Group 4. In its wetland state, this community is equivalent to p51 [*Tableland Lacustrine Herbfield*] identified by Tozer *et al.* (2010). Recognised as Draft VCA 636 [*Lacustrine Ephemeral Grassland of the South Eastern Highlands bioregion*] (Benson in prep).

Frequently occurring weeds: An unusual suite of weed species has been recorded for this community, reflecting not only its disturbance history but also its unique lacustrine environment. The most frequently recorded species are *Aster subulatus*, *Nassella dichotoma*, *Nassella neesiana*, *Hypochaeris radicata*, *Plantago coronopus* and *Polygonum aviculare.*

Threats: The community is subject to continuing grazing pressures at all sites, and is severely threatened by weed invasion at Lake Bathurst. At this location, recent and ongoing weed control is threatening some native components.

Reservation status: Not known to occur in any conservation reserves.

Extent of clearing: Unknown, although throughout its range, only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Benson, J.S. (in prep.) New South Wales vegetation classification and assessment: Part 4. Plant communities of the west South Eastern Highlands and Australian Alps bioregions. Botanic Gardens Trust, Sydney; Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report; Tozer, M.G., Turner, K., Keith, D.A., Tindall, D., Pennay, C., Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

r5: *Rytidosperma* sp. – *Austrostipa bigeniculata* – *Chrysocephalum apiculatum* tussock grassland of the South Eastern Highlands bioregion

Scientific Name: *Rytidosperma* spp. – *Austrostipa bigeniculata – Bothriochloa macra – Lomandra bracteata – Themeda australis – Chrysocephalum apiculatum*

Number of samples:	82
Richness [mean (±SD)]:	22 (6)
Slope (degrees):	(0) 1–4 (22)
Altitude (m asl):	(456) 568–709 (1021)
Ave. Annual Rainfall (mm):	(521) 611–658 (711)
Temp. Annual Range (°C):	(26.6) 27.9–28.3 (30.0)

Vegetation Description: Community r5 is a mid-dense to dense, low to tall tussock grassland dominated by *Rytidosperma* spp. (mainly *Rytidosperma carphoides* and *Rytidosperma auriculatum*), *Bothriochloa macra*, *Austrostipa bigeniculata* and *Themeda australis. Chrysocephalum apiculatum* and *Lomandra bracteata* are common components of the lower stratum. Other grasses and forbs are present, including *Panicum effusum*, *Plantago varia*, *Austrostipa scabra*, *Elymus scaber*, *Goodenia pinnatifida*, *Triptilodiscus pygmaeus*, *Calocephalus citreus*, *Schoenus apogon* and *Tricoryne elatior.* One of the very few NSW populations of *Lepidium hyssopifolium* is found in this community.

Isolated or scattered trees and tall shrubs may be present including *Eucalyptus melliodora*, *Eucalyptus blakelyi*, *Eucalyptus rubida*, *Eucalyptus bridgesiana, Eucalyptus pauciflora* subsp. *pauciflora* or *Acacia dealbata*. Smaller shrubs may occur including *Lissanthe strigosa*, *Daviesia genistifolia*, *Melichrus urceolatus* and *Acacia genistifolia.* Trees and shrubs increase in density where this community merges with the adjacent woodland communities. Relatively undisturbed sites have a variety of uncommon grassland forbs, including *Eryngium ovinum*, *Tricoryne elatior*, *Calocephalus citreus*, *Pimelea curviflora*, *Rutidosis leptorrhynchoides*, *Wurmbea dioica*, *Microtis* spp., *Dichopogon fimbriatus*, *Bulbine bulbosa* and *Calotis anthemoides.*

Community r5 is found on a variety of topographic situations, including footslopes, midslopes and flats and on a variety of substrates, including sedimentary strata, colluvium, alluvium or granite. The combined factors of severe winter and spring frosts, exposure to hot drying westerly winds in summer, and to a lesser degree seasonal waterlogging and cracking clays, limit the establishment of woody taxa in this community. This grassland is mainly found in the Murrumbateman subregion, but is also found in the Shoalhaven River valley. Degraded sites (i.e. lacking some of the main species that define this community) may be difficult to distinguish from degraded examples of Community r3 [*Rytidosperma sp. – Themeda australis – Juncus sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion*] or Community r7 [*Themeda australis – Rytidosperma* sp. – *Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq
Acaena ovina	1	54
Aristida spp.	1	22
Asperula conferta	1	43
Austrostipa bigeniculata	3	85
Austrostipa scabra	1	43
Bothriochloa macra	3	84
Calocephalus citreus	1	36
Chloris truncata	1	35
Chrysocephalum apiculatum	3	80
Convolvulus angustissimus	1	52
Desmodium varians	1	42
Dichondra repens	1	20

Elymus scaber	1	58
Eryngium ovinum	1	68
Euchiton involucratus	1	26
Glycine tabacina	1	27
Goodenia pinnatifida	1	58
Hypericum gramineum	1	21
Juncus spp.	1	27
Leptorhynchos squamatus	1	25
Lomandra bracteata	2	80
Microlaena stipoides	1	26
Oxalis perennans	1	48
Panicum effusum	1	64
Plantago varia	1	56
Poa sieberiana	1	32
Rumex brownii	1	59
Rumex dumosus	1	21
Rytidosperma carphoides	2	46
Rytidosperma spp.	4	96
Schoenus apogon	1	33
Solenogyne dominii	1	23
Themeda australis	2	64
Tricoryne elatior	1	44
Triptilodiscus pygmaeus	1	46
Vittadinia muelleri	1	59
Wahlenbergia spp.	1	73

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory*; NC Act 1980 – *Natural Temperate Grassland.*

Equivalent vegetation types: Community 1 (Benson 1994), Group 5 (Rehwinkel unpub.).

Frequently occurring weeds: The most frequently recorded weed species in this community include a number of common pasture weeds, but also some of the most damaging noxious weeds in the State. These include *Eragrostis curvula*, *Nassella trichotoma*, *Hypericum perforatum*, *Nassella neesiana*, *Hypochaeris radicata*, *Acetosella vulgaris*, *Vulpia* spp., *Cirsium vulgare* and *Phalaris aquatica.*

Threats: This community has been extensively cleared and remnants are subject to small-scale clearing, grazing pressures and nutrient run-on from adjacent fertilised crops and pastures. The abundance of several noxious weeds within this community is an indication of past disturbance, but also highlights the importance of managing against future impacts, particularly to native species diversity and cover.

Reservation status: Poorly reserved in NSW. Known from Queanbeyan NR and Dunlop NR. It is also informally reserved at Days Hill Reserve (a local government reserve at Bungendore).

Extent of clearing: Unknown, although throughout its range, only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Benson, J.S. (1994) The native grasslands of the Monaro region: southern tablelands of New South Wales. *Cunninghamia* 3: 609–650; Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

Plate r5: On dry sites in regions from the ACT and northwards, such as here at Queanbeyan Nature Reserve, Community r5 is generally dominated or co-dominated by *Austrostipa* spp., *Rytidosperma* spp. and *Bothriochloa macra*, with the most common forbs being *Chrysocephalum apiculatum* and several *Lomandra* spp.

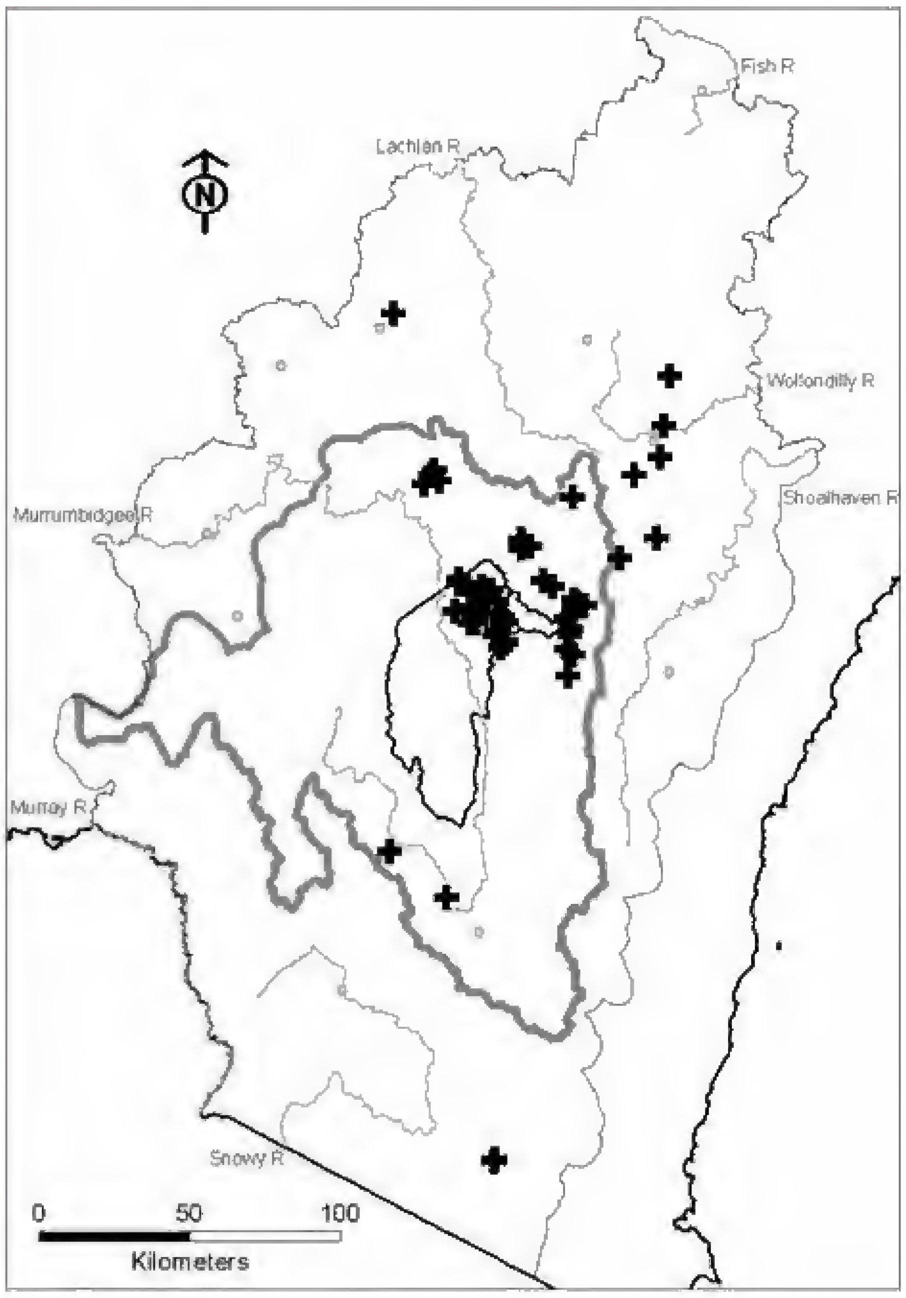

Fig. r5: Distribution of field samples assigned to this community.

r6: Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion

Scientific Name: *Poa sieberiana – Rytidosperma* **spp.** *– Themeda australis – Austrostipa scabra – Acaena ovina – Asperula conferta – Chrysocephalum apiculatum*

Number of samples:	110
Richness [mean (±SD)]:	22 (6)
Slope (degrees):	(0) 2–6 (13)
Altitude (m asl):	(674) 866–1016 (1206)
Ave. Annual Rainfall (mm):	(496) 518–612 (765)
Temp. Annual Range (°C):	(25.9) 27.3–28.2 (29.5)

Vegetation Description: Community r6 is an open to dense, mid-high to tall tussock grassland dominated by one or more of the following in the upper stratum: *Poa sieberiana*, *Rytidosperma* spp., *Themeda australis*, *Austrostipa scabra* and *Austrostipa bigeniculata*. There is a diversity of forbs and other grasses in the inter-tussock spaces, including *Chrysocephalum apiculatum*, *Acaena ovina*, *Asperula conferta*, *Wahlenbergia* spp., *Scleranthus diander*, *Elymus scaber*, *Plantago varia*, *Poa meionectes*, *Bothriochloa macra*, *Brachyscome heterodonta*, *Enneapogon nigricans* and *Leptorhynchos squamatus*. Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus lacrimans, Acacia dealbata* or *Acacia rubida*. Isolated patches of shrubs may also occur, generally containing *Einadia nutans*, *Melicytus* sp. 'Snowfields', *Cryptandra amara*, *Pimelea glauca*, *Discaria pubescens*, *Mirbelia oxylobioides* and *Dodonaea procumbens*. Trees and shrubs increase in density in ecotones with adjacent woodland communities or on rocky sites. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Geranium antrorsum*, *Rutidosis leiolepis, Swainsona sericea*, *Cullen tenax*, *Pimelea curviflora* and *Stackhousia monogyna.*

This community is found on a variety of substrates; most commonly on basalt and sedimentary strata, occasionally occurring on granite, and rarely on colluvium or alluvium. It commonly occurs on midslope, upperslope and plateau situations, and rarely on footslopes and flats. It occurs within the drier portions of the Monaro region, commonly referred to as the Monaro rainshadow. Severe winter and spring frosts, exposure to hot drying westerly winds in summer, periodic snow and the occurrence of cracking clays (particularly on colluvial soils derived from basalt) all serve to limit the establishment of woody taxa in this community. Community r2 [*Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion*] may be found in moist depressions and drainage lines adjacent to this community. Sites along the wetter fringe of the region, especially degraded sites (i.e. lacking some of the main species that define this community) may be confused with degraded examples of Community r7 [*Themeda australis – Rytidosperma sp. – Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion*].

Characteristic Species:

Species	C/A	Freq
Acaena ovina	2	87
Asperula conferta	2	81
Austrostipa bigeniculata	1	44
Austrostipa scabra	2	70
Bothriochloa macra	1	42
Brachyscome heterodonta	1	60
Brachyscome rigidula	1	25
Carex spp.	1	57
Chrysocephalum apiculatum	3	81
Convolvulus angustissimus	1	75
Crassula sieberiana	1	30
Cryptandra amara	1	24
Cullen tenax	1	23
Cymbonotus lawsonianus	1	35

Plate r6: Typical of the dry rain-shadow regions of the Monaro, such as here at Kuma Nature Reserve south of Cooma, Community r6 sites are dominated by *Poa sieberiana* and, in undisturbed areas, *Themeda australis*. A characteristic suite of forbs and shrubs include *Rutidosis leiolepis*, *Calotis glandulosa*, *Dodonaea procumbens* and *Melicytus* sp. 'Snowfields'.

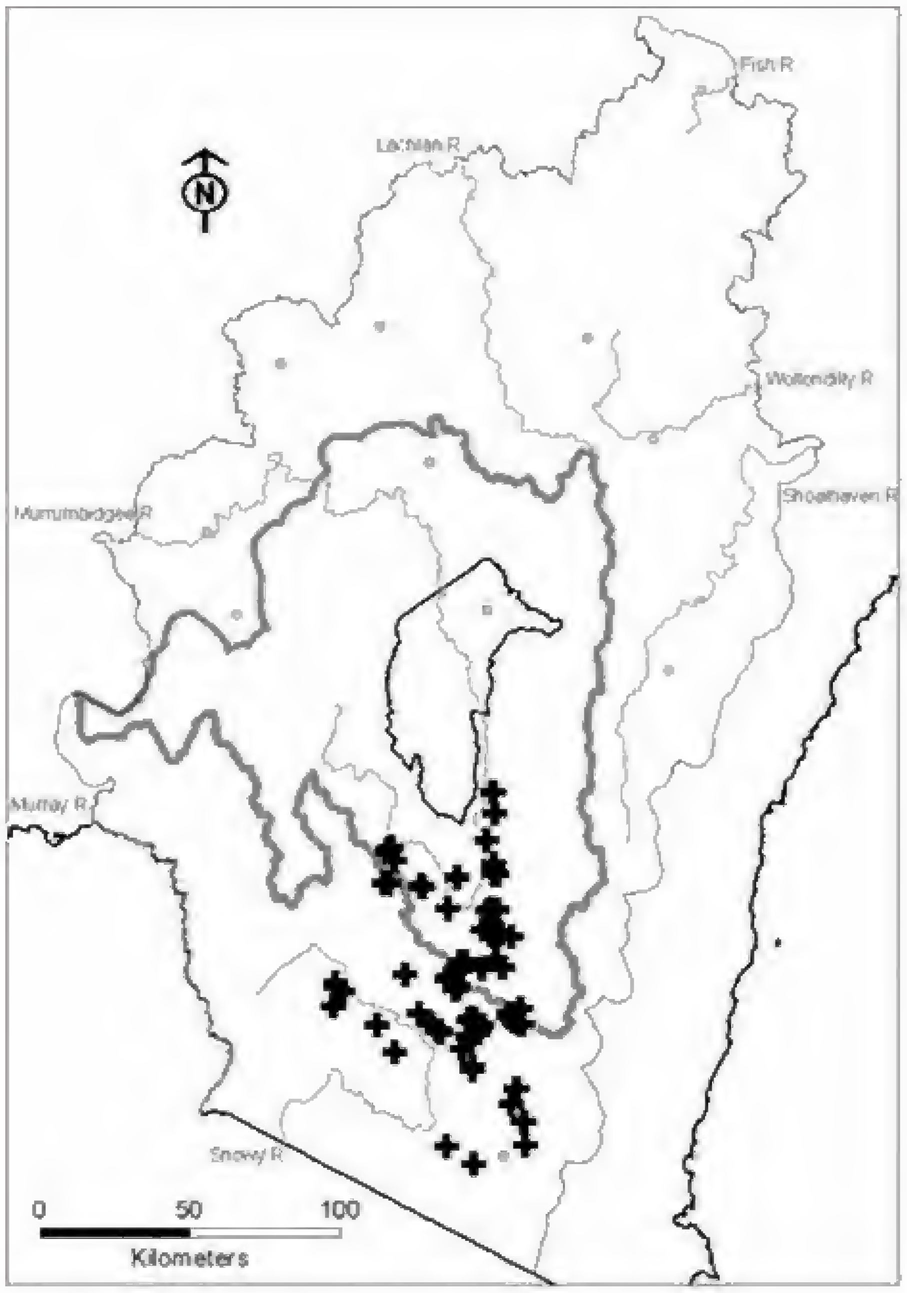

Fig. r6: Distribution of field samples assigned to this community.

Desmodium varians	1	28
Dichelachne spp.	1	29
Dichondra repens	1	25
Dichondra sp.A	1	39
Einadia nutans	1	27
Elymus scaber	2	72
Enneapogon nigricans	1	52
Epilobium spp.	1	37
Euchiton spp.	1	20
Geranium antrorsum	1	47
Glycine clandestina	1	21
Glycine tabacina	1	22
Goodenia pinnatifida	1	22
Leptorhynchos squamatus	1	40
Melicytus sp. 'Snowfields'	1	27
Oxalis perennans	1	47
Pimelea curviflora	1	21
Pimelea glauca	1	22
Poa meionectes	1	51
Poa sieberiana	4	94
Rumex brownii	1	49
Rytidosperma spp.	3	96
Scleranthus biflorus	1	33
Scleranthus diander	2	65
Solenogyne gunnii	1	30
Stackhousia monogyna	1	20
Swainsona sericea	1	33
Themeda australis	3	71
Vittadinia cuneata	1	37
Vittadinia muelleri	2	73
Vittadinia triloba	1	39
Wahlenbergia spp.	2	82

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory.*

Equivalent vegetation types: Group 6 (Rehwinkel unpub.), which includes Sub-groups 6a, 6b and 6c. These subgroups correspond with Benson (1994) Communities 4, 3b and 3a respectively. The higher diversity components of Community 5 (Benson 1994) also occur in this community.

Frequently occurring weeds: Like Community r5, the most frequently recorded weed species in this community include several common pasture weeds, as well as a number of noxious weeds. These include *Eragrostis curvula*, *Nassella trichotoma*, *Hypericum perforatum*, *Hypochaeris radicata*, *Acetosella vulgaris*, *Vulpia* spp., *Cirsium vulgare* and *Onopordum acanthium.*

Threats: This community has been extensively cleared and/or modified with remnants subject to small-scale clearing, weed invasion and grazing pressures.

Reservation status: Poorly reserved. Occurs in Kuma NR south-east of Cooma and Namadgi NP. Informally reserved at Old Cooma Common and at the Bush heritage Australia reserve, Scottsdale.

Extent of clearing: Unknown, although throughout its range, only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Benson, J.S. (1994) The native grasslands of the Monaro region: southern tablelands of New South Wales. *Cunninghamia* 3: 609–650; Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

r7: *Themeda australis – Rytidosperma* sp. *– Poa sieberiana* moist tussock grassland of the South Eastern Highlands bioregion

Scientific Name: *Themeda australis – Rytidosperma* spp. – *Poa sieberiana – Leptorhynchos squamatus – Chrysocephalum apiculatum*

Number of samples:	133
Richness [mean (±SD)]:	23 (7)
Slope (degrees):	(0) 1–4 (14)
Altitude (m asl):	(283) 641–820 (1185)
Ave. Annual Rainfall (mm):	(509) 647–716 (995)
Temp. Annual Range (°C):	(25.0) 26.7–28.0 (30.1)

Vegetation Description: Community r7 is an open to dense, mid-high to tall tussock grassland with the upper stratum dominated by *Themeda australis* and with a sub-dominance of *Rytidosperma* spp. and *Poa sieberiana*. Inter-tussock spaces are generally occupied by herbaceous taxa including *Chrysocephalum apiculatum*, *Leptorhynchos squamatus*, *Microlaena stipoides*, *Wahlenbergia* spp., *Asperula conferta*, *Juncus* spp., *Acaena ovina*, *Elymus scaber*, *Schoenus apogon* and *Plantago varia*. Isolated or scattered trees may be present, including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus rubida*, *Eucalyptus aggregata, Eucalyptus melliodora, Acacia dealbata* or *Acacia mearnsii*. Isolated shrubs or patches of shrubs may also occur including *Melicytus* sp. 'Snowfields', *Hovea linearis*, *Pimelea glauca*, *Lissanthe strigosa*, *Daviesia latifolia*, *Daviesia mimosoides*, *Leucopogon fraseri*, *Melichrus urceolatus*, *Bossiaea buxifolia*, *Cryptandra amara* and *Kunzea parvifolia*. Trees and shrubs increase in density at ecotones with adjacent woodland communities. Relatively undisturbed sites have a variety of uncommon grassland forbs including *Hypericum japonicum*, *Tricoryne elatior*, *Pimelea curviflora*, *Microtis* spp., *Prasophyllum petilum, Calocephalus citreus*, *Eryngium ovinum*, *Craspedia* spp., *Ranunculus lappaceus*, *Rutidosis leptorrhynchoides, Bulbine bulbosa*, *Stackhousia monogyna* and *Wurmbea dioica*.

This community is found on midslopes and footslopes and to a lesser degree on flats. It is most commonly found on sedimentary, colluvium and granite lithologies, and infrequently on alluvium and basalt. It is distributed widely, being found in the Murrumbatemen and Crookwell subregions of the South Eastern Highlands, the Shoalhaven Valley, and in moister outer fringes of the Monaro region beyond rainshadow areas. Outliers occur near Tumbarumba, Tumut, Bathurst and Orange. Severe winter and spring frosts, exposure to hot, drying westerly winds in summer, occasional waterlogging and the occurrence of cracking clays limit the establishment of woody taxa.

Community r7 grades into Community r2 [*Poa labillardierei – Themeda australis – Juncus sp. wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands bioregion*] and Community r3 [*Rytidosperma sp. – Themeda australis – Juncus sp. tussock grassland of occasionally wet sites of the South Eastern Highlands bioregion*] in moist depressions and drainage lines. Where distribution overlaps, it may be confused with Community r6 [*Dry tussock grassland of the Monaro in the South Eastern Highlands bioregion*]. Confusion between this community and those above may occur where the communities intergrade, especially in degraded sites (i.e. those lacking some of the main diagnostic taxa that define Community r7).

Plate r7: Widespread in the wetter locations such as this floristically diverse site at Steve's TSR near Delegate, Community r7 is dominated by *Themeda australis*, with the forbs *Chrysocephalum apiculatum*, *Leptorhynchos squamatus* and *Asperula conferta* often occurring in high cover.

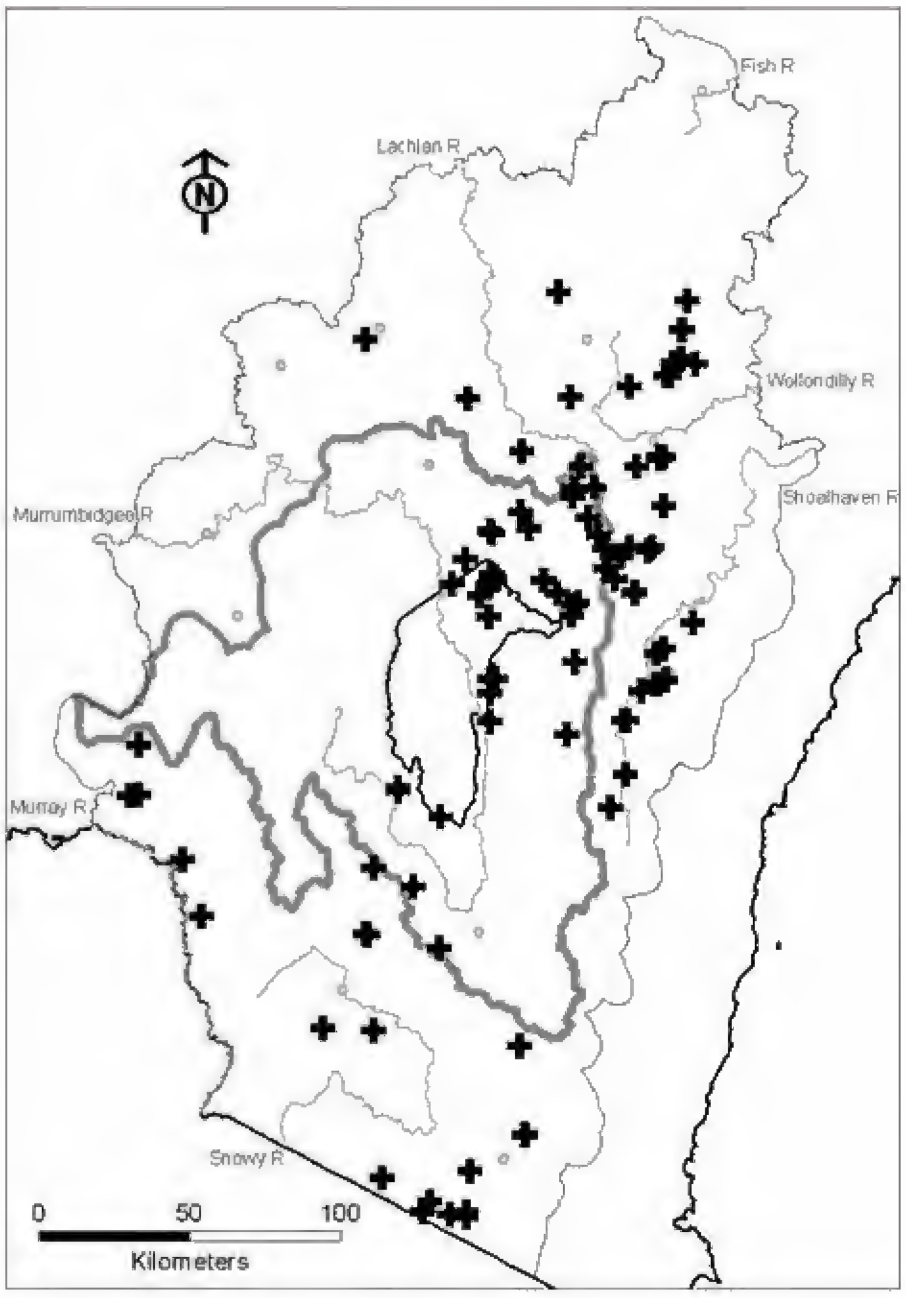

Fig. r7: Distribution of field samples assigned to this community.

Characteristic Species:

Species	C/A	Freq
Acaena ovina	1	61
Asperula conferta	1	59
Austrostipa bigeniculata	1	21
Bothriochloa macra	1	21
Carex spp.	1	35
Chrysocephalum apiculatum	2	79
Convolvulus angustissimus	1	40
Dichelachne spp.	1	26
Drosera peltata	1	26
Elymus scaber	1	50
Epilobium spp.	1	29
Eryngium ovinum	1	21
Euchiton spp.	1	64
Glycine tabacina	1	20
Gonocarpus tetragynus	1	42
Haloragis heterophylla	1	26
Hypericum japonicum	1	39
Juncus spp.	1	63
Leptorhynchos squamatus	2	70
Lomandra bracteata	1	40
Luzula spp.	1	36
Microlaena stipoides	1	49
Microtis spp.	1	26
Oxalis perennans	1	46
Panicum effusum	1	29
Pimelea curviflora	1	32
Poa labillardierei	1	25
Poa sieberiana	2	77
Rumex dumosus	1	54
Rytidosperma spp.	2	87
Schoenus apogon	1	41
Scleranthus biflorus	1	21
Scleranthus fasciculatus	1	20
Solenogyne dominii	1	30
Solenogyne gunnii	1	24
Themeda australis	6	100
Tricoryne elatior	1	39
Triptilodiscus pygmaeus	1	39
Vittadinia muelleri	1	27
Wahlenbergia spp.	1	69

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory*; NC Act 1980 – *Natural Temperate Grassland.*

Equivalent vegetation types: Community 2 (Benson 1994), Group 7 (Rehwinkel unpub.).

Frequently occurring weeds: Like other grassland communities, the most frequently recorded weed species in this community include several common pasture weeds, as well as a number of noxious weeds. These include *Eragrostis curvula*, *Nassella trichotoma*, *Hypericum perforatum*, *Hypochaeris radicata*, *Acetosella vulgaris*, *Vulpia* spp. *Cirsium vulgare* and *Onopordum acanthium*.

Threats: This community has been extensively cleared and/or modified with remnants subject to small-scale clearing, weed invasion and grazing pressures.

Reservation status: Poorly reserved. Occurs in Turallo NR and Scabby Range NR, as may occur in conservation reserves in the ACT. Likely to occur at Dangelong NR. It is also known from a local government reserve near Bungendore (Days Hill Reserve) and Nature Conservation Trust covenanted lands in the upper Shoalhaven catchment.

Extent of clearing: Unknown, although throughout its range, only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Benson, J.S. (1994) The native grasslands of the Monaro region: southern tablelands of New South Wales. *Cunninghamia* 3: 609–650; Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

r8: *Themeda australis – Lomandra filiformis – Aristida ramosa* dry tussock grassland in the South Eastern Highlands bioregion

Scientific Name: *Themeda australis – Lomandra filiformis – Rytidosperma* spp. *– Microlaena stipoides – Aristida ramosa – Chrysocephalum apiculatum*

Number of samples:	18
Richness [mean (±SD)]:	26 (9)
Slope (degrees):	(0) 1–8 (13)
Altitude (m asl):	(453) 512–683 (876)
Ave. Annual Rainfall (mm):	(620) 658–673 (725)
Temp. Annual Range (°C):	(26.3) 27.5–28.3 (28.4)

Vegetation Description: Community r8 is an open to dense, mid to tall tussock grassland with the upper stratum dominated by *Themeda australis*, *Aristida ramosa*, *Lomandra filiformis* and *Austrostipa densiflora.* Other gramonoids may include *Rytidosperma* spp., *Microlaena stipoides*, *Lomandra multiflora*, *Austrostipa scabra* and *Poa sieberiana.* Inter-tussock spaces are generally occupied by a diverse range of forbs including *Chrysocephalum apiculatum*, *Wahlenbergia* spp., *Pimelea curviflora*, *Goodenia hederacea* subsp. *hederacea* and *Gonocarpus tetragynus.* Isolated or scattered trees may be present including *Eucalyptus pauciflora* subsp. *pauciflora*, *Eucalyptus melliodora, Jacksonia scoparia*, *Acacia mearnsii* or *Acacia dealbata.* Isolated patches of shrubs may also occur including *Lissanthe strigosa*, *Hibbertia obtusifolia*, *Melichrus urceolatus*, *Astroloma humifusum*, *Bursaria spinosa*, *Dillwynia sericea* and *Dodonaea boroniifolia.* Trees and shrubs increase in density at ecotones with adjacent woodland communities, and shrubs may be especially dense in rocky areas. Relatively undisturbed sites have a variety of herbecaous taxa uncommon in grassland communities including *Pimelea curviflora*, *Tricoryne elatior*, *Dianella revoluta*, *Boerhavia dominii*, *Stylidium graminifolium sens. lat.*, *Bulbine glauca*, *Cymbopogon refractus* and *Dianella longifolia.*

This community is most commonly found on midslopes and upperslopes, although it can infrequently occur on rocky flats adjacent to creeks. It is found most commonly on soils derived from sedimentary strata and infrequently from granite, usually on steep exposed north-west-facing slopes, including in river gorges. Sites generally overlook extensive valleys or plains; thus they are subjected to hot, drying north-westerly winds in summer, which is a main determinant of species composition in this community. It is sparsely distributed, with isolated occurrences in the Yass, Goulburn, Tarago and Braidwood regions. Often, Community r8 occurs adjacent to Community r7 [*Themeda australis – Rytidosperma* sp. *– Poa sieberiana moist tussock grassland of the South Eastern Highlands bioregion*], which occurs on moister sites downslope. Confusion between these two communities is expected to occur where the communities intergrade, and especially in degraded examples (i.e. lacking some of the main diagnostic taxa that define these communities). Community r8 does not occur in the Monaro, where it is generally replaced by a subtype of Community r6 [*Dry Tussock Grassland of the Monaro in the South Eastern Highlands bioregion*].

Characteristic Species:

Species	**C/A**	**Freq**
Acacia rubida	1	21
Acaena ovina	1	21
Aristida ramosa	1	58
Astroloma humifusum	1	26
Austrostipa bigeniculata	1	21
Austrostipa densiflora	2	47
Austrostipa scabra	1	47
Boerhavia dominii	1	32
Bothriochloa macra	1	37
Brachyloma daphnoides	1	21
Bulbine glauca	1	26
Bursaria spinosa	1	26
Carex spp.	1	21
Cheilanthes spp.	1	37
Chrysocephalum apiculatum	2	63
Convolvulus angustissimus	1	21
Crassula sieberiana	1	21
Cryptandra amara	1	21
Cymbopogon refractus	1	26
Dianella longifolia	1	26
Dianella revoluta	1	42
Dillwynia sericea	1	26
Diuris punctata	1	21
Dodonaea boroniifolia	1	26
Elymus scaber	1	26
Enneapogon nigricans	1	26
Eragrostis spp.	1	26
Euchiton spp.	1	53
Glycine tabacina	1	37
Gonocarpus tetragynus	1	42
Goodenia hederacea subsp. *hederacea*	1	53
Hibbertia obtusifolia	1	42
Hovea linearis	1	21
Hypericum gramineum	1	21
Laxmannia gracilis	1	21
Leptorhynchos squamatus	1	32
Lissanthe strigosa	1	47
Lomandra filiformis	2	100
Lomandra longifolia	1	32
Lomandra multiflora	1	58
Luzula spp.	1	26
Melichrus urceolatus	1	37
Microlaena stipoides	2	63
Microtis spp.	1	21
Opercularia hispida	1	21
Oxalis perennans	1	42
Panicum effusum	1	37
Pimelea curviflora	1	63
Plantago varia	1	21
Poa sieberiana	1	42
Rumex brownii	1	26
Rytidosperma pallidum	1	21
Rytidosperma spp.	2	68
Schoenus apogon	1	26
Solenogyne dominii	1	42
Stylidium graminifolium sens. lat.	1	32
Thelymitra spp.	1	21
Themeda australis	5	95
Tricoryne elatior	1	53
Triptilodiscus pygmaeus	1	26
Vittadinia muelleri	1	26
Wahlenbergia spp.	2	74
Westringia eremicola	1	21

Plate r8: Found on dry, steep, often west-facing sites, like this one in the Jerrabatgulla Creek area near Braidwood, Community r8 sites are often dominated or co-dominated by *Themeda australis* and *Aristida ramosa* and have a high cover of *Lomandra filiformis* and *Chrysocephalum apiculatum*, along with a diversity of other forbs and sub-shrubs.

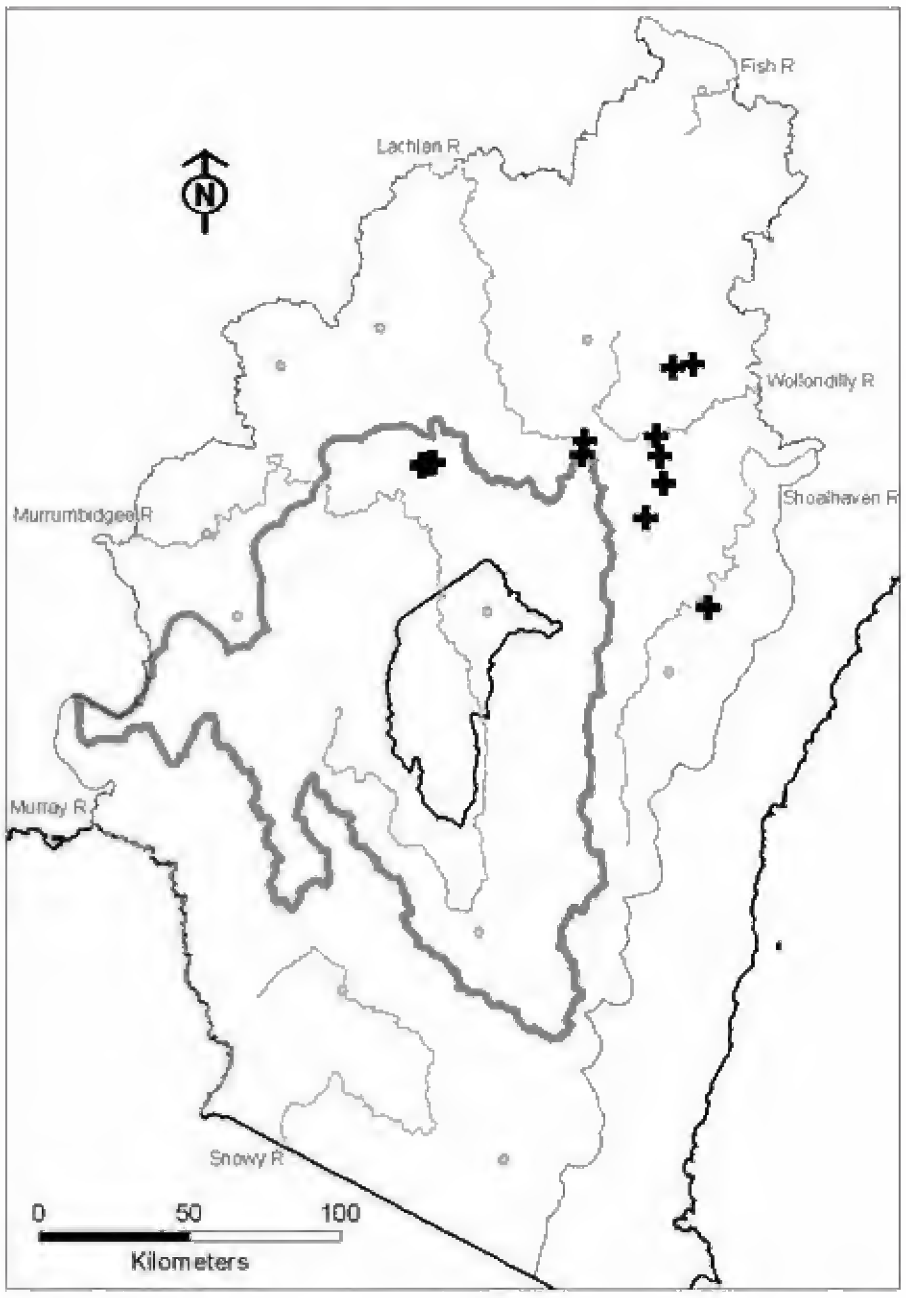

Fig. r8: Distribution of field samples assigned to this community.

Threatened communities: EPBC Act 1999 – *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory*. Although not yet assessed in the ACT, if confirmed this community would be listed under the NC Act 1980 – *Natural Temperate Grassland.*

Equivalent vegetation types: Group 8 (Rehwinkel unpub.).

Frequently occurring weeds: Consistent with other natural grassland communities described here, the most common weeds were either common pasture species, or noxious weeds. These include *Eragrostis curvula*, *Nassella trichotoma*, *Hypericum perforatum*, *Hypochaeris radicata*, *Acetosella vulgaris*, *Vulpia* spp., *Cirsium vulgare* and *Onopordum acanthium.*

Threats: This community has been extensively cleared and/or modified with remnants subject to small-scale clearing, weed invasion and grazing pressures.

Reservation status: Not known to occur in any formal conservation reserves, however it occurs on Nature Conservation Trust covenanted land in the upper Shoalhaven catchment.

Extent of clearing: Unknown, although throughout its range, only 3% of the *Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory* TEC remains in high ecological integrity, relative to its pre-European settlement extent (Environment ACT 2006).

References: Environment ACT (2006) National recovery plan for natural temperate grassland of the southern tablelands (NSW and ACT): an endangered ecological community. Environment ACT, Canberra; Rehwinkel, R. (unpublished) Revision of PATN analysis of grassland associations within the Natural Temperate Grassland Endangered Ecological Community in the Southern Tablelands of NSW. August 2009. NSW Department of Environment and Climate Change, Queanbeyan. Unpublished Report.

Appendix 2: Equivalent communities in recent classifications

Prefixes: **a** (McDougall & Walsh 2007); **b** (Benson 1994); **bj** (Benson & Jacobs 1994); **g** (Gellie 2005); **e, m** and **p** (Tozer *et al.* 2010), **R** (Rehwinkel unpub.), **VCA** (Benson *et al.* 2010)

NOTE: In a new classification such as this, where new plot data are added and the spatial extent is different from previous classifications, exact equivalence between plant communities identified in different classifications is unlikely. In this table we identify the closest match to previous classifications and, where analysis of previous communities found no match in the current classification, we indicate which new plant communities the majority of plots were assigned to.

Plant Community (this study)	**Equivalents and similar communities**
a14: Prickly Snow-grass – Tufted Sedge subalpine valley grassland of the Australian Alps Bioregion	a14: Subalpine valley grassland; b7: *Poa costiniana – Epilobium billardierianum* subsp. *cinereum – Brachyscome scapigera – Asperula gunnii* montane, sod-tussock grassland
a2: Alpine Baeckea – Swamp Heath – Candle Heath – Sphagnum wetland of the Australian Alps Bioregion (Bog)	Combination of a2: *Richea continentis – Carpha nivicola – Sphagnum cristatum* wet heathland and a3: *Baeckea gunniana – Callistemon pityoides – Sphagnum cristatum* wet heathland
a22: Snow–grass – Herbfield Celmisia – Woolly Billy-button grassland of the Australian Alps Bioregion	Combination of a18: *Poa fawcettiae – Uncinia sulcata* grassland and a22: *Poa fawcettiae – Euphrasia collina* grassland
a30: Dwarf Snow-grass – Fine-leaved Snow-grass – Silver Carraway – Granite Buttercup grassland of the Australian Alps Bioregion	Combination of a30: *Poa hiemata – Poa clivicola* grassland and a31: *Poa hookeri* grassland; b6: *Poa* spp. – *Geranium antrosum – Scleranthus biflorus – Leptorhynchos squamatus – Ranunculus graniticola* montane sod-tussock grassland
a33: Leafy Bossiaea – Mountain Cassinia – Yellow Kunzea – Alpine Hovea heathland of the Australian Alps Bioregion	Combination of a33: Northern Alps *Hovea montana* open heathland, a35: *Bossiaea foliosa – Epacris petrophila* heathland and a36: Broadway *Bossiaea foliosa* closed heathland
a34: Weeping Snow shrub-grass woodland of the Australian Alps Bioregion	a34: *Eucalyptus lacrimans* low open woodland
a38: Kangaroo Grass – Rodd's Bedstraw – Alpine Sunray grassland of steep limestone slopes in the Australian Alps Bioregion	a38: *Themeda triandra – Leucochrysum albicans* grassland
a39: Feldmark Heath – Carpet Heath – Snow-grass heath of the Australian Alps Bioregion	a39: Kosciuszko alpine *Epacris – Kunzea* open heathland
a42: Epacris – Fine-leaved Snow-grass – Bog Parrot-pea grassy heathland of the Australian Alps Bioregion	a42: Epacris celata – *Poa clivicola* open Heathland
a43: Dwarf Bossiaea – Kangaroo Grass low open heathland of the Australian Alps Bioregion	a43: *Bossiaea riparia* dwarf heathland
a46: Alpine Mint-bush – Alpine Orites – Kosciuszko Nematolepis shrubland in the Australian Alps Bioregion	Combination of a23: *Grevillea australis – Nematolepis ovatifolia* open heathland and a46: *Nematolepis ovatifolia – Prostanthera cuneata* closed heathland
a51: Mountain Plum Pine – Crag Wallaby-grass – Snow-daisy low sparse shrubland of rock outcrops of the Australian Alps Bioregion	a51: *Austrodanthonia alpicola – Grevillea australis* open heathland
a54: Mountain Plum Pine – Tall Rice-flower shrubland of screes and boulder-fields of the Australian Alps Bioregion	a54: *Podocarpus lawrencei* closed heathland
a6: Dwarf Buttercup – Mud Pratia – Tufted Sedge herbfield of shallow depressions in the Australian Alps Bioregion	a6: *Lobelia surrepens – Ranunculus millanii* herbfield
a7: Bog Buttercup – Creeping Raspwort herbfield of wetland margins in the Australian Alps Bioregion	a7: *Hypericum japonicum – Ranunculus pimpinellifolius* herbfield
a8: Tufted Sedge – Mud Water-milfoil – Tufted Hair-grass sedgeland of the Australian Alps Bioregion (Fen)	a8. Fen
a9: Tufted Sedge – Small River-buttercup – Common Reed aquatic herbfield of waterways in the Australian Alps and South Eastern Highlands Bioregions	a9: Aquatic
e24: Mountain Gum – Snow Gum very tall dry shrubby woodland to open forest primarily in the Kybeyan – Gourock subregion of the South Eastern Highlands Bioregion	Largely equivalent to e24: Subalpine Dry Shrub Forest (but includes plots originally assigned to p338). g64: Southern East Tableland Edge Shrub/Grass Dry Forest is divided between e24 and e26 (the latter of which occurs to the east outside the study area)
e59: Small-fruit Hakea – Mountain Baeckea – Myrtle Tea-tree subalpine bog heathland on the coastal ranges of the South Eastern Highlands Bioregion	e59: Southeast Sub-alpine Bog
g36: Button Tea-tree – Yellow Kunzea – Burgan dry shrubland on skeletal ridges primarily of the Namadgi Region	g36: Montane / Sub-Alpine Dry Rocky Shrubland

L3: Freshwater sedge-herb marsh of shallow ephemeral lakes of the eastern South Eastern Highlands Bioregion	Approximately equivalent to bj3
L4: Freshwater sedge-herb marsh of deep semi-permanent and/or slightly saline wetlands of the eastern South East ern Highlands Bioregion	A modification and range extension of bj4
m31: Ribbon Gum – Snow Gum – Shiny Cassinia tall shrub-grass woodland to open forest of gullies in quartz-rich ranges in the Monaro and Kybeyan-Gourock subregions of the NSW South Eastern Highlands	Largely a combination of g73: Eastern Tableland Dry Shrub/Grass Forest and g74: South Eastern Tablelands Dry Shrub/Grass/Herb Forest
m51: Brittle Gum – Scribbly Gum shrub-grass tall dry sclerophyll woodland on exposed quartz-rich slopes and ridges at primarily in the Monaro and Kybeyan-Gourock subregions of the South Eastern Highlands Bioregion	Closest to g115: South East Tablelands Dry Shrub/Tussock Grass Forest but including some plots originally assigned to other communities (mainly g73, g75, g109, g110)
p10: Black Sheoak – Silvertop Ash tall shrubby dry sclerophyll woodland to open forest primarily in the Bungonia subregion of the South Eastern Highlands Bioregion	A westward extension of p10: Eastern Tablelands Dry Forest; g15: North East Tableland Dry Shrub Forest
p14: Red Stringybark – Scribbly Gum – Redanther Wallaby Grass tall grass-shrub dry sclerophyll woodland to open forest on loamy ridges of the central South Eastern Highlands Bioregion	A westward extension of p14; largely a combination of g114: Tablelands Dry Shrub/Tussock Grass Forest; and parts of g109: Widespread Tablelands Dry Shrub/Tussock Grass Forest and g121: Western Slopes Grass/Herb Dry Forest.
p220: Ribbon Gum – Snow Gum tableland flats tall grassy woodland primarily on granitoids in the Kybean-Gourock and Monaro subregions of the South Eastern Highlands Bioregion	Largely equivalent to p220: Southern Tableland Flats Forest but contains several plots assigned in the same classification to p520: Tableland Swamp Flats Forest. Contains plots from g73: Eastern Tableland Dry Shrub/Grass Forest and g74: South Eastern Tablelands Dry Shrub/Grass/Herb Forest.
p32d: River Sheoak dry forest on sand/gravel alluvial soils along major watercourses of the South Eastern Highlands and upper South Western Slopes Bioregions	VCA 85: River Oak forest and woodland wetland of the NSW South-western Slopes and South Eastern Highlands Bioregions
p338: Brown Barrel wet sclerophyll very tall grass-herb open forest primarily of the Gourock and Tallaganda Ranges in the South Eastern Highlands Bioregion	p338: Southern Range Wet Forest; combination of g55: Eastern Tableland Fern/Herb/Grass Moist Forest, g56: Tableland and Escarpment Moist Herb/Fern Grass Forest and part of g95: Tableland Acacia Moist Herb Forest.
p520: Ribbon Gum swamp very tall woodland on sandy alluvial soils along drainage lines of the eastern South Eastern Highlands Bioregion	Largely equivalent to p520: Southern Tableland Flats Forest. Contains plots from g89: Eastern Tablelands Acacia/Herb/Grass Forest and g146: Tableland Dry Herb/Grass Woodland.
p56: Mountain Tea-tree – Small-fruit Hakea – River Lomatia riparian shrubland of the eastern South Eastern Highlands Bioregion	Equivalent to p56
p8: Silvertop Ash – Narrow-leaved Peppermint tall shrubby dry sclerophyll woodland to open forest primarily on sedimentary ridges of the eastern South Eastern Highlands Bioregion	p8: Tableland Ridge Forest; a combination of g59: Eastern Tableland and Escarpment Shrub/Fern Dry Forest and g112: Eastern Tablelands Dry Shrub Forest.
r1: Sub-montane moist tussock grassland of the South Eastern Highlands Bioregion	r1: Sub-montane moist tussock grassland of the South Eastern Highlands Bioregion
r2: River Tussock – Kangaroo-grass – Rush wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands Bioregion	b8: *Poa labillardieri* tall tussock grassland, R2: River Tussock – Kangaroo-grass – Rush wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands Bioregion, VCA635: River Tussock – Kangaroo – Grass – Rush wet tussock grassland of footslopes, drainage lines and flats of the South Eastern Highlands Bioregion.
r3: Wallaby-grass – Kangaroo Grass – Rush tussock grassland of occasionally wet sites of the South Eastern Highlands Bioregion	r3: Wallaby-grass – Kangaroo Grass – Rush tussock grassland of seasonally wet sites of the South Eastern Highlands Bioregion. VCA637: Wallaby-grass – Kangaroo Grass – Rush tussock grassland of seasonally wet sites of the South Eastern Highlands Bioregion.
r4: Lacustrine ephemeral grassland of the South Eastern Highlands Bioregion	r4: Lacustrine ephemeral grassland of the South Eastern Highlands Bioregion. VCA636: Lacustrine Ephemeral Grassland of the South Eastern Highlands Bioregion.
r5: Wallaby-grass – Tall Speargrass – Common Everlasting tussock grassland of the South Eastern Highlands Bioregion	b1: *Danthonia* spp. – *Asperula conferta* – *Bothriochloa macra* low grassland on the northern Monaro, r5: Wallaby-grass – Tall Speargrass – Common Everlastings tussock grassland of the South Eastern Highlands Bioregion.
r6: Dry tussock grassland of the Monaro in the South Eastern Highlands Bioregion	Combination of b3: *Themeda australis* – *Poa sieberiana* – *Chrysocephalum apiculatum* – *Acaena ovina* tall grassland and b4: *Poa sieberiana* – *Acaena ovina* grassland on basalt, southern Monaro; r6: Dry tussock grassland of the Monaro in the South Eastern Highlands Bioregion.

r7: Kangaroo Grass – Wallaby-grass – Snow-grass moist tussock grassland of the South Eastern Highlands Bioregion	b2: *Themeda australis – Juncus filiformis* grassland of the ACT; r7: Kangaroo Grass – Wallaby-grass – Snow-grass moist tussock grassland of the South Eastern Highlands Bioregion.
r8: Kangaroo Grass – Purple Wire-grass – Wattle Mat-rush dry tussock grassland in the Southern Tablelands region of the South Eastern Highlands Bioregion	r8: Kangaroo Grass – Purple Wire-grass – Wattle Mat-rush dry tussock grassland in the Southern Tablelands region of the South Eastern Highlands Bioregion.
L12: Freshwater sedge-herb marsh of shallow, commonly inundated wetlands of the eastern South Eastern Highlands Bioregion	Combination of bj1 and bj2.
p23: Red Stringybark – Broad-leaved Peppermint tall dry sclerophyll grassy woodland on loamy rises primarily in the Bungonia subregion of the South Eastern Highlands Bioregion	Largely equivalent to p23: Tableland Hills Grassy Woodland but with many new plots to the west and some plots originally assigned to p24: Tableland Grassy Box-Gum Woodland.
p24: Yellow Box – Blakely's Red Gum tall grassy woodland on undulating sedimentary and acid-volcanic substrates in the Goulburn area of the South Eastern Highlands Bioregion	Largely equivalent to p24: Tableland Grassy Box-Gum Woodland. but with many new plots to the west
p9: Brittle Gum – Scribbly Gum tall shrubby dry sclerophyll woodland on infertile low ridges and hills primarily of the Bungonia subregion of the South Eastern Highlands Bioregion	Largely equivalent to p9: Tableland Low Woodland but including some plots originally assigned to p14, p15 and p23.
u105: Broad-leaved Peppermint – Brittle Gum – Red Stringybark tall shrub-grass dry sclerophyll woodland to open forest of lower ranges of the western South Eastern Highlands and upper South Western Slopes Bioregions	Largely a combination of g108: Western Tablelands Dry Herb/Grass Forest and g110: Tablelands Dry Shrub/Grass Forest but with some plots originally assigned to other communities (mainly g103 and g109).
u118: Black Sallee grass-herb woodland in drainage depressions and moist valley flats in the South Eastern Highlands and Australian Alps Bioregions	No equivalent. All but one plot was not available for previous classifications.
u148: Red Stringybark – Red Box grass-forb tall woodland to open forest of the upper South Western Slopes and western South Eastern Highlands Bioregions	No clear equivalent; contains many new plots and plots originally assigned to g116: Western Slopes Herb/Grass Woodland, g119: Western Tablelands Dry Shrub/Grass Forest, g120: Western Slopes Shrub/Herb/Grass Dry Forest and g121: Western Slopes Grass/Herb Dry Forest and has affinities with VCA290: Red Stringybark – Red Box – Long-leaved Box – Inland Scribbly Gum tussock grass – shrub low open forest on hills in the southern part of the NSW South-western Slopes Bioregion
u150: Broad-leaved Peppermint – Mountain Gum tall grass-forb woodland to open forest of the South Eastern Highlands and Australian Alps Bioregions	Most similar to g103: Western Montane Dry Fern/Grass Forest but contains plots originally assigned to several other communities (mainly g75, g105, g107, g109, g110).
u152: Robertson's Peppermint – Red Stringybark very tall grass-forb sheltered woodland to open forest of the southwest South Eastern Highlands and upper South Western Slopes Bioregions	Largely a combination of g93: Western Tablelands Herb/Grass Dry Forest and g94: South West Slopes Acacia Dry Herb/Grass Forest but including some plots originally assigned to other communities (mainly g103, g104 and g119)
u158: Alpine Sallee mid-high shrub-grass subalpine woodland of the Australian Alps Bioregion	Combination of g128: Sub-alpine Dry Shrub/Herb Woodland and g130: Sub-alpine Shrub/Grass Woodland with many new plots.
u159: Black Sassafras temperate rainforest of wet sheltered slopes in the Australian Alps Bioregion	Largely equivalent to g172: Kosciuszko Western Escarpment Cool Temperate Rainforest
u165: Robertson's Peppermint very tall shrubby woodland to open forest primarily of the Bondo subregion of the South Eastern Highlands	Similar to VCA295; incorporates g106: Montane Dry Shrub/Tussock Forest but including some plots originally assigned to other communities (mainly g103, g104 and g82)
u173: River Red Gum +/- Apple Box very tall grass-forb riparian woodland on alluvial flats in the South Eastern Highlands and upper South Western Slopes Bioregions	Largely defined by new plots but incorporates g43: Western Slopes Riparian Moist Sedge Woodland.
u178: Yellow Box – Apple Box tall grassy woodland of the South Eastern Highlands	Largely defined by new plots but contains several plots previously assigned to g160: Northern Slopes Dry Grass Woodland
u18: Bundy – Broad-leaved Peppermint mid-high shrubby woodland to open forest on granite substrates primarily in the Namadgi Region	Probably simiar or equivalent to g79: Montane Dry Shrub/Tussock Grass Forest.
u181: River Bottlebrush – Burgan rocky riparian shrubland in the South Eastern Highlands and upper South Western Slopes Bioregions	Largely defined by new plots; contains plots originally assigned to g82: Western Montane Acacia Fern/Herb Forest.
u19: Blakely's Red Gum – Yellow Box +/– White Box tall grassy woodland of the Upper South Western Slopes and western South Eastern Highlands Bioregions	Incorprates g117: Western Slopes Dry Grass Woodland and contains plots previously assigned to g116: Western Slopes Herb/Grass Woodland, g154: Tableland Dry Grassy Woodland and g160: Northern Slopes Dry Grass Woodland
u191: Black Cypress Pine – Brittle Gum tall dry woodland on hills primarily in the Cooma Region	No equivalent but possibly related to g79: Montane Dry Shrub/Tussock Grass Forest.
u193: Small-fruit Hakea – Drumstick Heath – Swamp Heath Subalpine Swamp Heathland of the Australian Alps and western South Eastern Highlands Bioregions	Largely defined by new plots; contains plots originally assigned to g123: Montane Wet Heath/Bog and g124: Western Montane Wet Heath/Herb Grass Woodland.

u20: Kurrajong – Blackthorn – Kangaroo Grass mid-high shrub-grass open woodland on limestone karsts in the Wee Jasper area	No equivalent; defined by new plots.
u207: Jounama Snow Gum – Snow Gum mid-high shrubby woodland on granitoids primarily of the Namadgi Region	Probably equivalent to g127: Sub-alpine Dry Shrub/Herb/Grass Woodland but mostly defined by new plots.
u21: Broad-leaved Peppermint – Candlebark tall dry sclerophyll woodland to open forest of quartz-rich ranges of the upper South East Highlands and lower Australian Alps Bioregions	Largely defined by new plots but contains plots previously assigned to g74: South Eastern Tablelands Dry Shrub/Grass/Herb Forest and g75: Tablelands Shrub/Tussock Grass Forest
u22: Mountain Gum – Snow Gum grass-forb very tall woodland to open forest of the Australian Alps and South Eastern Highlands Bioregions	Incorporates g97: Montane Acacia/Dry Shrub/Herb/Grass Forest and g100: ACT Montane Dry Shrub/Grass Forest with plots from g95: Tableland Acacia Moist Herb Forest, g96: Tableland Tussock Grass/ Herb Forest, g99: Montane Dry Shrub/Herb/Grass Forest, g101: North-Western Montane Dry Shrub/Herb/Grass Forest, g102: Brindabella Montane Dry Fern/Grass Forest, g103: Western Montane Dry Fern/ Grass Forest, and g104: Tableland Acacia/Herb/Grass Forest
u23: Snow Gum – Drumstick Heath – Myrtle Tea-tree tall woodland to open forest of drainage depressions primarily of the South Eastern Highlands Bioregion	Defined by many new plots but includes plots previously assigned to g124: Western Montane Wet Heath/Herb Grass Woodland and g146: Tableland Dry Herb/Grass Woodland.
u239: Alpine Ash – Mountain Gum +/– Snow Gum wet sclerophyll open forest of the Australian Alps and South Eastern Highlands Bioregions	No clear equivalent; mostly new plots but incorporates some plots from g86, g87, g99 and g102
u27: Snow Gum – Candlebark tall grassy woodland in frost hollows and gullies primarily of the South Eastern Highlands Bioregion	No equivalent. Defined by plots not used in previous classifications. May have some affinities with g100.
u28: Snow Gum – Mountain Gum – Daviesia mimosoides tall dry grass-shrub subalpine woodland to open forest of the Australian Alps and South Eastern Highlands Bioregions	Mostly defined by new plots but contains some plots previously assigned to g98: Western Montane Moist Shrub Forest
u29: Apple Box – Broad-leaved Peppermint tall shrub-grass woodland primarily on granitoids of the South Eastern Highlands Bioregion	No equivalent; defined by plots not used in previous classifications.
u40: Alpine Ash very tall wet sclerophyll woodland primarily of the Australian Alps Bioregion	Closest to g87: Western Escarpment Moist Shrub/Herb/Grass Forest but with many new plots and a few plots from g82 and g86
u43: Bundy – Hickory Wattle – Drooping Sheoak – Western Wedding Bush tall grassy open woodland Serpentinite in the Coolac-Goobarragandra area of the upper NSW Southwestern Slopes Bioregion	Equivalent to VCA301: Drooping Sheoke – *Ricinocarpus bowmannii* – grasstree tall open shrubland of the Coolac – Tumut Serpentinite Belt.
u52: Ribbon Gum – Robertson's Peppermint very tall wet sclerophyll open forest primarily of the Bondo Subregion of the South Eastern Highlands Bioregion	Largely a combination of g82: Western Montane Acacia Fern/Herb Forest, g83: Montane Riparian Moist Shrub/Grass/Herb Forest and g102: Brindabella Montane Dry Fern/Grass Forest
u53: Mountain Gum – Blackwood tall wet sclerophyll open forest primarily on granitoids of the Australian Alps and western South Eastern Highlands Bioregions	Most closely related to g86: Western Sub-alpine Moist Shrub Forest but including some plots originally assigned to g85
u66: Bundy – Red Stringybark mid-high grassy herbaceous open woodland of the South Eastern Highlands and Upper Slopes Subregion of the South Western Slopes Bioregion	No equivalent; defined by plots not used in previous classifications.
u78: Snow Gum mid-high grassy woodland of the South Eastern Highlands Bioregion	Comprises plots mostly from p22: Frost Hollow Grassy Woodland and p24: Tableland Grassy Box-Gum Woodland. The community is effectively a subset of those communities.

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Limonium hyblaeum (Plumbaginaceae), a cushion plant invading coastal southern Australia

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Abstract: The Sicilian endemic herbaceous perennial plant *Limonium hyblaeum* (family Plumbaginaceae) is rapidly becoming a serious weed in South Australia and Victoria, where it invades saltmarshes and rocky coastal sites exposed to salt spray. It has small, light seeds that float and remain viable in sea water and which can also be dispersed readily by wind, animals and vehicles. It can form dense, extensive mats and buds sprouting from rhizomes allow encroachment into dense native vegetation. It seems certain to be apomictic and is readily able to become dominant.

Forming dense, compact cushions which accumulate large amounts of fibrous peat, *Limonium hyblaeum* is the first cushion plant to become naturalized in Australia; the importance of the cushion habit as an adaptation to salt spray is under-appreciated.

Some control measures for *Limonium hyblaeum* have begun in Victoria, but much remains to be done there and in the other southern Australian states; a ban on the sale of the species by nurseries is urgently required.

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Introduction

The Sicilian endemic herbaceous perennial plant *Limonium hyblaeum* Brullo (Sicilian Sea Lavender) (family Plumbaginaceae) is naturalized in Western Australia, South Australia and Victoria (AVH 2013). Erben (1986) was first to apply the name *Limonium hyblaeum* to Australian specimens. At the same time he recorded it from England, where it is still present (Online Atlas of the British and Irish Flora (OABIF) 2013) and from Chile (a single specimen). The first Australian flora account to recognize it under that name is Walsh (1996).

The first published record of its weedy behaviour in Australia is that by Adair *et al*. (2008) where it appears in a Victorian list of 'Lower Risk Weeds'. Since then, in Victoria there has been increasing awareness of two major infestations leading to the collapse of native plant communities and giving rise to the view that *Limonium hyblaeum*, with *Lophopyrum ponticum* (Podp.) A. Love and *Spartina anglica* C.E. Hubb. are the three most important weed threats to Victorian saltmarshes (Adair 2012). The aims of the present paper are to briefly review what is known of the biology of *Limonium hyblaeum*, the history of its spread in Australia, and of its effects on native plant communities. *Limonium hyblaeum* is the only Sicilian endemic and the only cushion plant to become naturalized in Australia.

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The Species

Limonium (family Plumbaginaceae) is a cosmopolitan genus with about 350 species (Kubitzki 1993), most of which are herbaceous perennials from coastal or inland saline, gypseous or alkaline soils (http://en.wikipedia.org/wiki/Limonium; seen 21 Jan 2013). The genus is often taxonomically difficult; apomixis is very common, so that many species are microspecies occupying extremely limited areas (Cowan *et al.* 1998). The centre of diversity of the genus is the Mediterranean region (Cowan *et al.* 1998).

Limonium hyblaeum was described by Brullo (1980), having previously been lumped with other species. It is endemic to Sicily, where it is a species of rocky coasts with a very localized distribution (Brullo & Pavone 1981). It is a putatively apomictic tetraploid; if apomictic, then a new population can be founded by a single individual (Cowan *et al.* 1998).

Limonium hyblaeum plants are herbaceous perennials to 25cm high. As in many *Limonium* species, individual plants of *Limonium hyblaeum* have a shoot system usually made up of numerous small rosettes forming a dense cluster which can often become a hemispherical cushion (Figs. 1 and 2) or extensive mat by production of new rosettes. In addition, new rosettes are often produced along rhizomes, especially at the edges of patches of plants. These rosettes become new plants if the rhizome breaks for any reason (Rodrigo *et al.* 2012).

A similar but better-understood rhizomatous *Limonium* is *Limonium vulgare* Mill. whose individual plants can form clones up to 4 m across and rhizomes can extend for 60 cm per year allowing the species to occupy hundreds of hectares as a near-monoculture. Its lifespan is up to 30 yr (Zadoks 2005). For *Limonium vulgare* and *Limonium humile* Mill. it is clear that reproduction by seed is only important when a new area is being invaded. Subsequent reproduction is largely by vegetative spread (Boorman 1968). The same seems to be true for *Limonium hyblaeum* (Rodrigo *et al.* 2012).

Limonium hyblaeum has small seeds 2 mm long (Walsh 1996). The fruit is a dry, membranous, one-seeded achene (Kubitzki 1993). In the genus and in *Limonium hyblaeum* itself, it is assumed that single seeds and the fruits are light enough to be readily dispersed both by wind and by animals (including birds, humans and rabbits), as well as by vehicles (Kubitzki 1993, Adair 2012, Rodrigo *et al.* 2012). On the south coast of England, it is assumed to be dispersed by gulls (OABIF 2013).

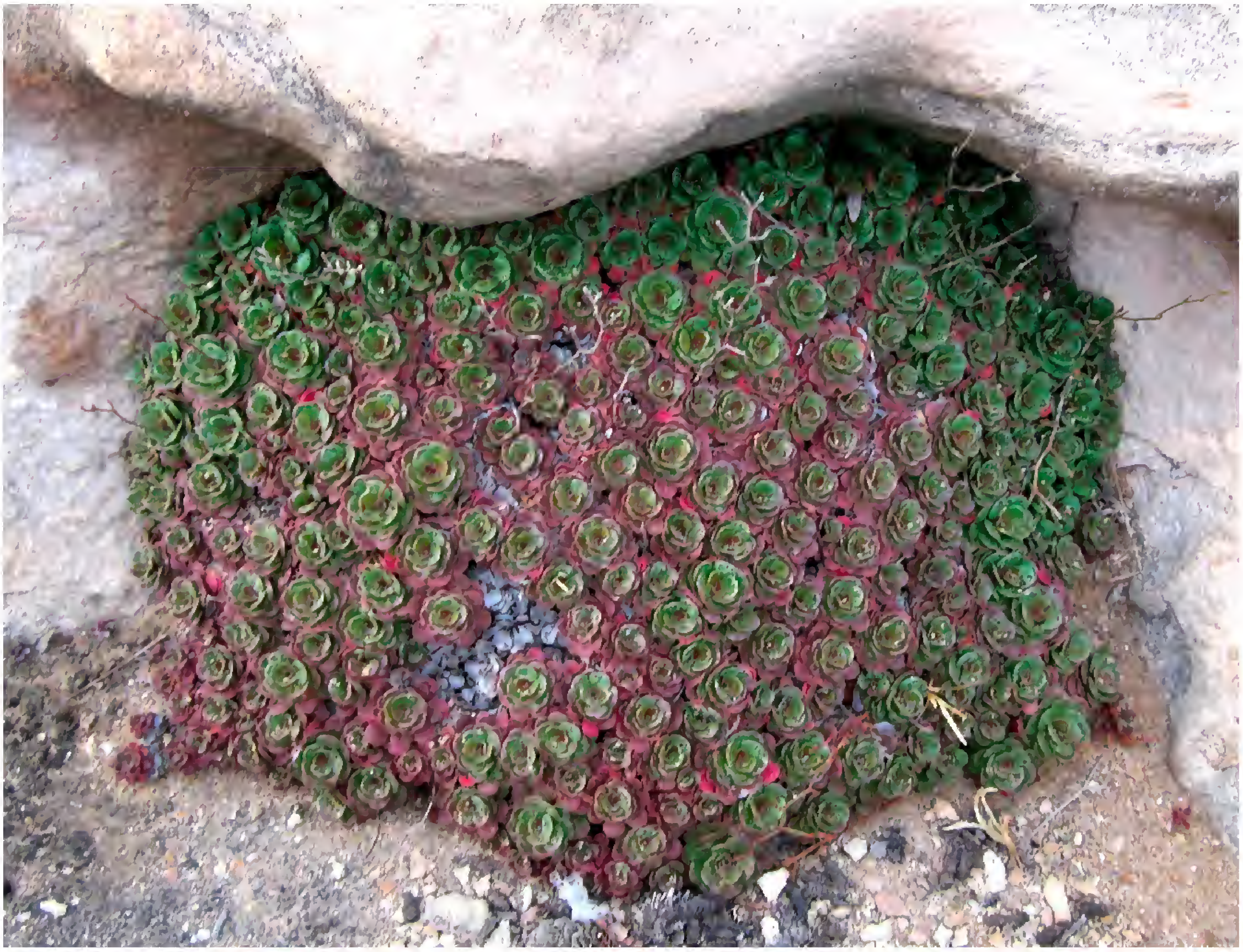

Fig. 1. Cushion of *Limonium hyblaeum* 20cm wide showing dense canopy and numerous small rosettes. On calcarenite, Robe, South Australia (photo R.J. Bates).

Limonium humile and *Limonium vulgare* seeds can float and survive long periods in sea water and the presence of germinating seeds in drift line debris shows that dispersal in sea water is important in colonizing new areas (Boorman 1968). Field observations suggest that the same is very likely to be true for *Limonium hyblaeum* (Rodrigo *et al.* 2012).

Like other species of *Limonium* examined, *Limonium hyblaeum* has salt-secreting glands on its leaves and stems, which can secrete a range of ions taken up from the soil solution, including sodium and chloride (Faraday & Thomson 1986).

The habitat

Records of *Limonium hyblaeum* from Sicily and England are from rocky coastal sites exposed to salt spray (Brullo 1980, OABIF 2013), as are many of the Australian ones (Adair 2012, herbarium specimen labels at AD–Adelaide) but it is now clear that in Victoria it can survive periodic tidal inundation and can invade and suppress native coastal salt marsh vegetation (Adair 2012, Rodrigo *et al.* 2012).

Of the rocky coastal sites, many in South Australia are on limestone (Fig. 1), as are all those in England (specimen labels at AD, OABIF 2013), while many in Victoria are

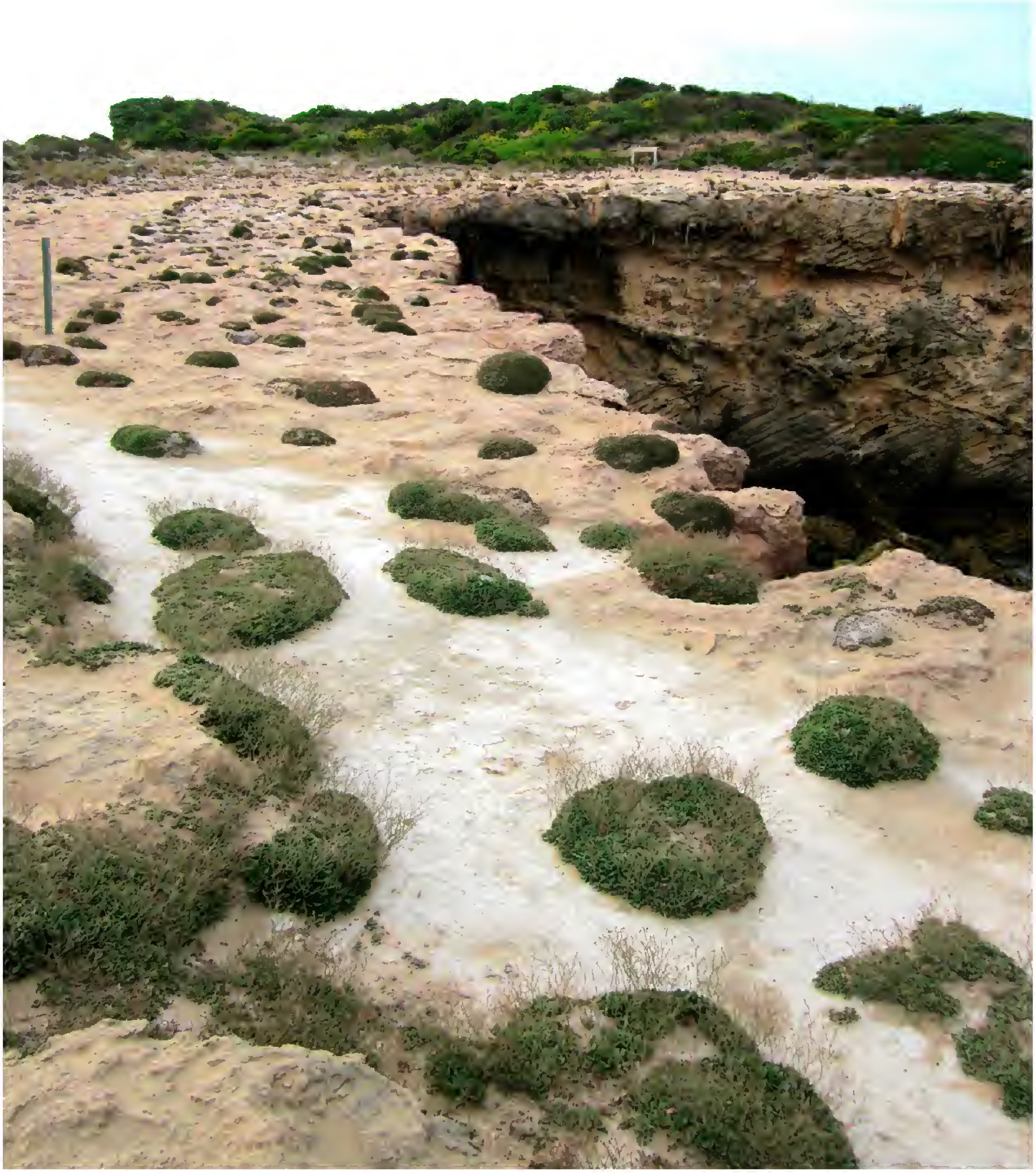

Fig. 2. Cushions of *Limonium hyblaeum* on coastal calcarenite clifftop, Robe, South Australia (photo R.J. Bates).

on basalt (Adair 2012) suggesting some connection with reasonably high soil pH (Adair 2012) or calcium status.

Nearly all records are from coastal sites with elevated NaCl levels from salt spray or tides. However, three specimens at AD are from inland sites. The roadside gravel record (Brodie 3174) looks likely to be non-saline, as do some of the occurrences listed in Adair (2012).

History of invasion in Australia

South Australia

The earliest record of a naturalized specimen in Australia is from Port Adelaide in 1889 (Toelken 1987). From 1889 to 1959 there are nine collections from suburban Adelaide and a 1932 one from Eyre Peninsula near Port Lincoln (specimens held at AD). Wider spread followed: Yorke Peninsula (by 1966), Victor Harbour (by 1973), the South East (by 1982), and Kangaroo Island (by 1987). Spread continues in all these regions.

The western limit for the AD specimens is Baird Bay near Streaky Bay (Brodie no. 1981) but in 2012 it was seen well to the west at Fowlers Bay, but not at the Nullarbor Plain cliff top lookouts further west in South Australia (J. Eichler pers. comm..).

Victoria

The five Victorian collections are all coastal; four, including the oldest (1984), are from an extensive stand at Port Fairy that must have originated years earlier (AVH 2013, N.G. Walsh pers. comm.). The other collection is a 2004 one from the Cheetham Salt Works at Point Henry near Geelong (AVH 2013) which is from the only other extensive Victorian stand (Adair 2012). There are six small patches scattered between the two, two of which have now been deliberately eliminated (Adair 2012).

New South Wales

The single AVH (2013) record is from 2003 from a very localized patch near Lake Cargelligo in central NSW (non-coastal), but a coastal record made in 2011 from saltmarsh on Saratoga Island near Gosford (specimen at UNSW: N. Rea 9522) needs further investigating in case it is not yet too late to eradicate the species there.

Western Australia

The six Western Australian records are all coastal (Fig, 3), with three from suburban Perth, the earliest in 1973. The other three are from two different areas up to 400 km N of Perth (dates 1981–2003). (AVH 2013).

The major infestations

For Victoria, Adair's (2012) overview clearly shows two major infestations. Firstly, around Port Fairy, it is dense and concentrated for about 5 km of coastline (Adair 2012) and completely encircles the outer edge of the closely adjacent Griffiths Island in a band up to 4 m wide with 100% cover in places. Much of this involves invasion of salt marsh (Rodrigo *et al.* 2012). For good images of this infestation, see Carr (2012). Secondly, at Cheetham Salt Works, Point Henry, near Geelong, the infestation size was 30m^2 in 2010, but became 1.5 ha in 2011, a 500-fold increase (Adair 2012). I assume from the images in Adair (2012) that at least part of this site is on well-drained sandy or shelly rises.

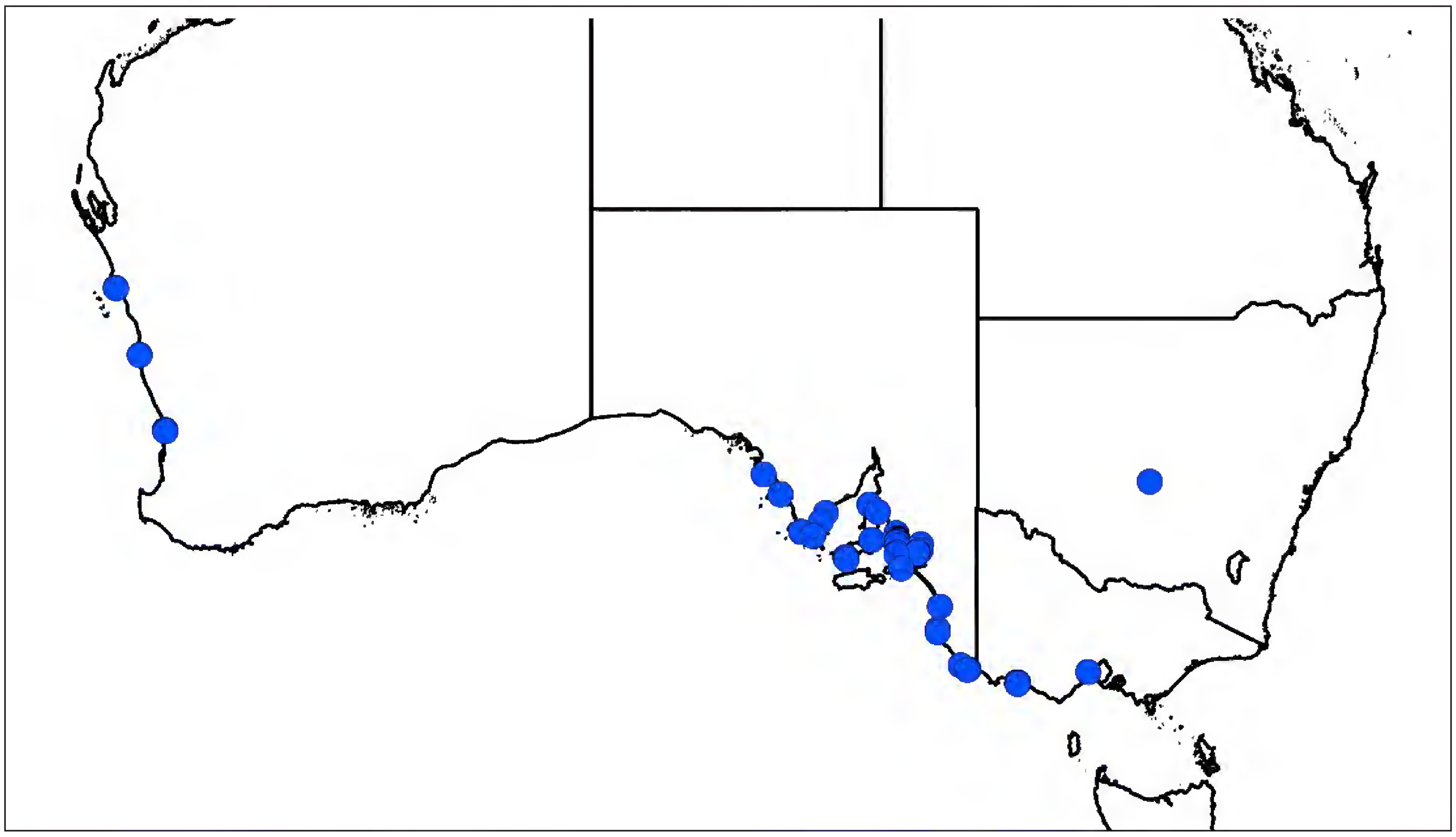

Fig. 3. Distribution of *Limonium hyblaeum* in Australia (AVH 2013). A recent record for coastal NSW is dealt with in the text.

There have been no systematic surveys for *Limonium hyblaeum* in South Australia, Western Australia or New South Wales. In South Australia, notes on herbarium specimens at AD suggest serious problems at a minimum of three sites: a) Robe 2009 'forms a thick monoculture…. very, very common.' Brodie 796. b) Port Elliot 2006 'absolutely thick' and excluding native flora. Murfet 5147. c) Elliston 2010 'dense stands… found along road for many miles coming into town.' Brodie 1972. All three stands involve rocky coastal sites.

Mode of introduction

Limonium hyblaeum is on sale at a few specialist nurseries in Australia and is grown for cut flowers and as an ornamental garden plant. The Port Fairy infestation reportedly started with a garden escape (Adair 2012) and in the coastal South Australian town of Marino, *Limonium hyblaeum* (locally called *Statice*) has spread from a garden planting, down a road verge and into a Conservation Park (specimen labels at AD; E.L. Robertson 242, 496).

Another South Australian *Limonium hyblaeum* collection at AD (from Coffin Bay) is annotated 'Introduced with other *Limonium* spp. to help combat soil salinity.' (C.R.Alcock 6687; 1979. Alcock was a government weeds officer). Further data are badly needed to see if this practice still occurs in any area; deliberate introduction of salt-tolerant species for agriculture and salt-land remediation has lead to other weed problems, such as the cases of *Bassia scoparia* (L.) A.J. Scott and *Puccinellia ciliata* Bor (Boon *et al*. 2011).

Ease of dispersal for *Limonium hyblaeum* by animals, wind and water is noted above. The means by which the species reached Australia, Chile and England from Sicily (Erben 1986) are unknown; introductions as a garden plant are perhaps the most likely.

Current control actions

The Victorian Department of Sustainability and Environment (DSE) helped to organize workshops on the *Limonium hyblaeum* weed problem at Geelong Botanic Gardens on 31 May 2012 and Phillip Island on 12 September 2012. Successful elimination of two small populations by hand-pulling was described, as were effective herbicide treatments (Adair 2012). Another result was subsequent DSE public communications describing the species, urging vigilance in uninvaded areas, stressing the importance of early detection and giving instructions if found (e.g. South Gippsland Landcare Network 2012).

I have not been able to find a reference to any control actions at all in other states.

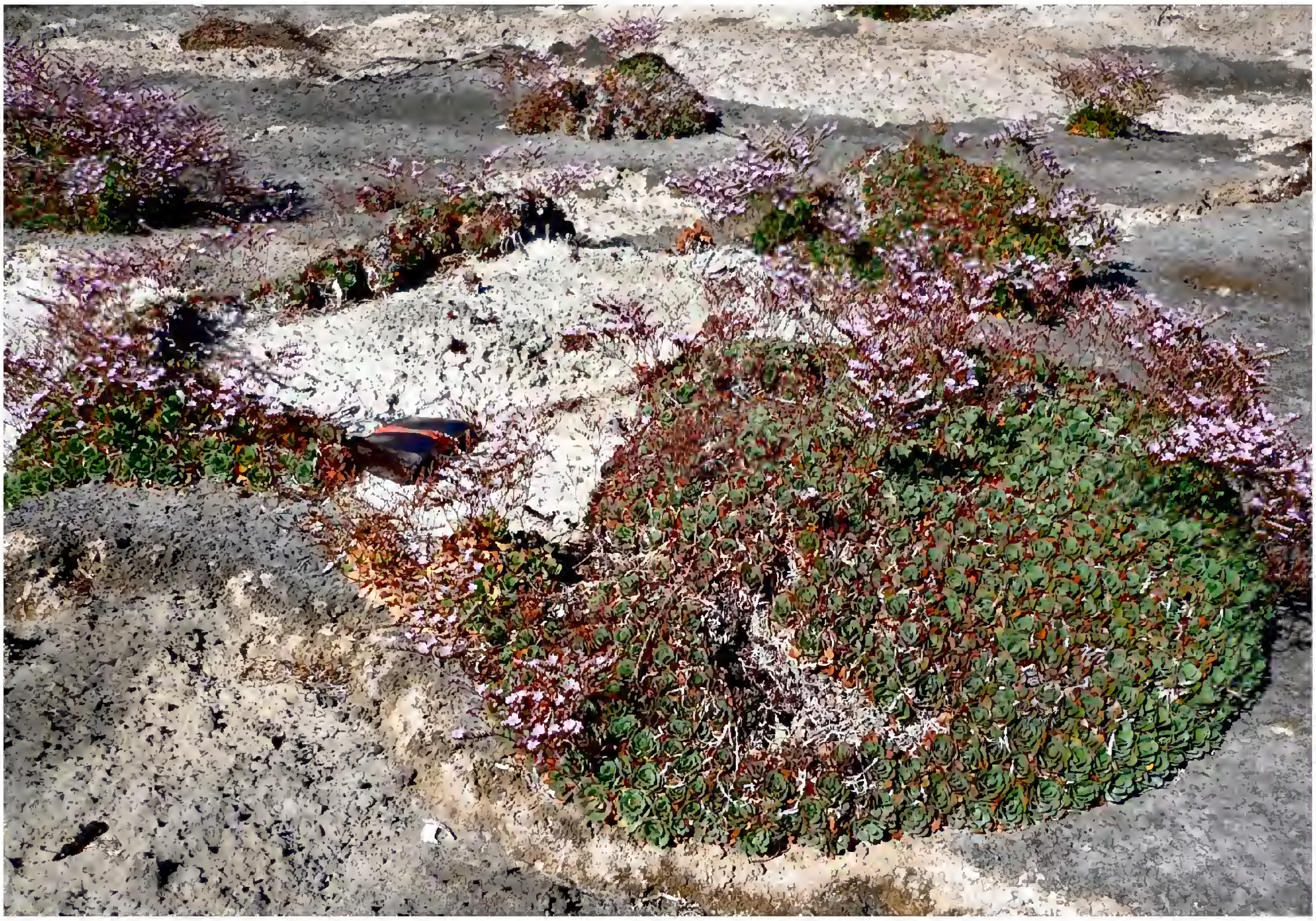

Fig. 4. Degenerating cushion of *Limonium hyblaeum* 40cm wide. Mounds of light grey to white fibrous peat can be seen in left part of cushion and sitting on grey calcarenite in background. Coffin Bay, South Australia (photo A.N. Parsons).

Limonium and the cushion habit

Cushion plants are defined as chamaephytes and hemicryptophytes that, growing singly, take on a hemispherical or subhemispherical shape due to the close branching of their shoots and their short internodes (Parsons & Gibson 2009), resulting in a smooth, dense, uniform shoot surface. At least 60 taxa occur in lowland southern Australia (Parsons & Gibson 2009).

There are several genera in the Plumbaginaceae in which species are commonly pulvinate (i.e. cushion-like) (Kubitzki 1993) including alpine cushion plants like *Armeria caespitosa* (Gomez Ortega) Boiss. in DC (Garcia-Camacho *et al.* 2012). In Sicily and the surrounding islands, at least three species of *Limonium*, including *Limonium hyblaeum* (Figure1), commonly occur as cushion plants (Brullo 1980). The occurrence of *Limonium hyblaeum* in Australia constitutes the first time a cushion plant has naturalized here.

For *Limonium hyblaeum*, like most lowland cushion plants, it is common to find plants both in cushion and non-cushion form (see Parsons & Gibson 2009). The cushions are compact and accumulate large amounts of fibrous peat within the cushion (Fig. 4) like some other cushion species (Parsons & Gibson 2009). The large amounts of peat might imply considerable plant longevity, as suggested on different grounds for some other *Limonium* species (Boorman 1968).

In stands of *Limonium hyblaeum*, it is common to find old plants which are gradually dying back, with a progressively widening gap in the middle of the shrub, leaving a ring of living shoots around the perimeter (Fig. 5). This is identical to the degenerate phase of growth described by Watt (1955) for *Calluna* and other shrubs.

The association of the cushion habit with the salt spray zone of exposed coasts has been pointed out for some species, both in the Mediterranean (Nimis 1981) and in southern Australia (Parsons & Gibson 2009). The smooth, uniform surface of the cushion and its shape minimize the amount of salt spray intercepted; any shoot that extends beyond the common smooth surface will be exposed to a higher load of salt spray. The only reference I know dealing with this in *Limonium* is Schweingruber *et al.* (2006) for *Limonium caprariense* (Font Quer & Marcos) Pignatti, but the general phenomenon is dealt with by Boyce (1954). In the genus *Limonium,* clearly the cushion habit is more likely to be found in species which can occur in the salt spray zone than in species like *Limonium vulgare* which occur only in saltmarshes.

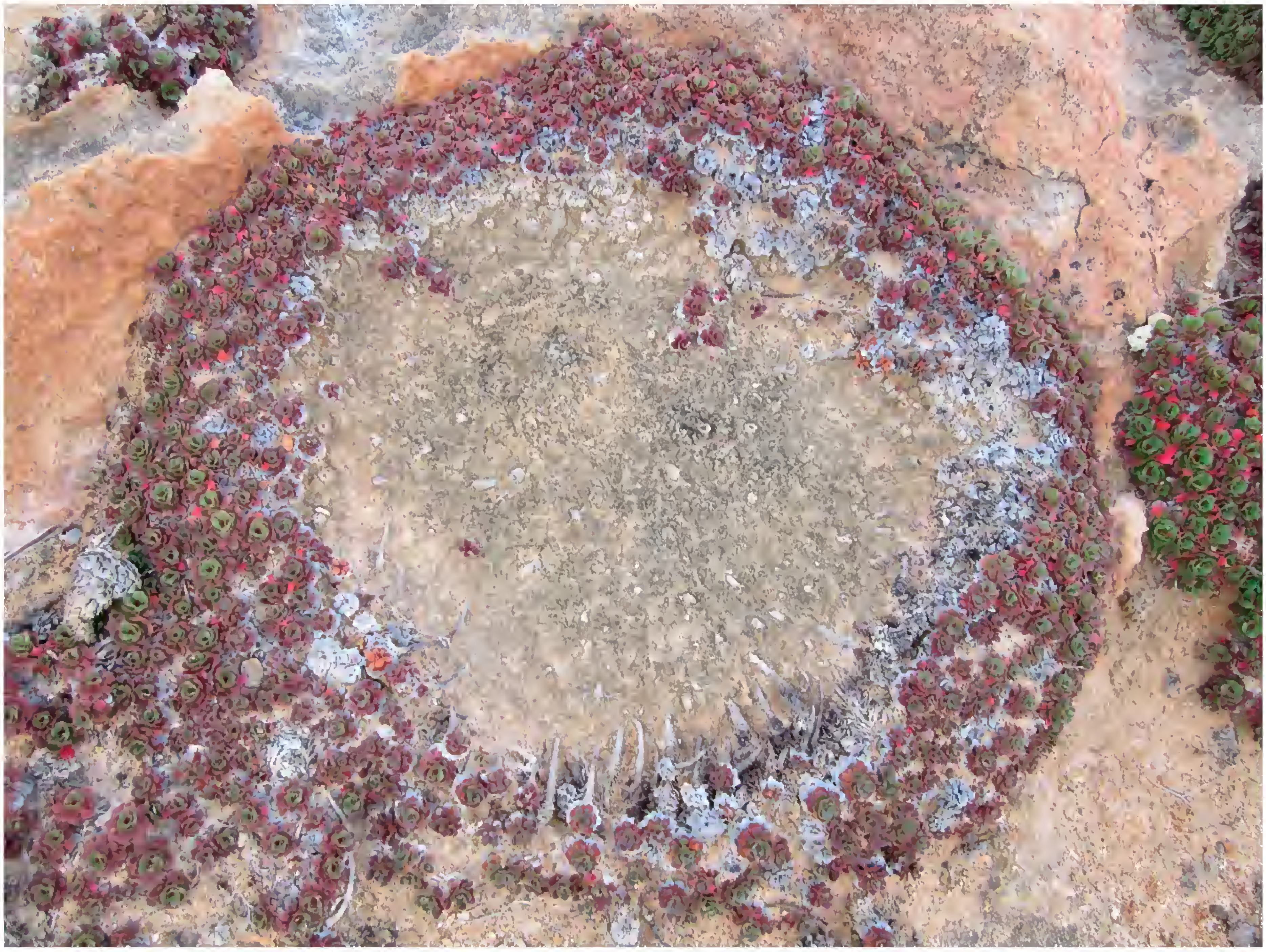

Fig. 5. Degenerating cushion of *Limonium hyblaeum* 25cm wide with progressively widening gap in centre. This is filled with light grey fibrous peat. On calcarenite, Robe, South Australia (photo R.J. Bates).

Concluding discussion

Being a cushion plant endemic to Sicily, *Limonium hyblaeum* is an unusual weed in the Australian context. However, in terms of traits important for weediness (Pheloung *et al.* 1999), it is clear why it is becoming so successful. The seeds have high dispersability in sea water and by wind, animals and vehicles. It seems certain to be apomictic. It can form extensive mats; also buds sprouting from rhizomes allow encroachment into dense vegetation (Rodrigo *et al.* 2012). It is readily able to become dominant.

Both in the salt spray zone of rocky coastlines and in saltmarshes, it is clearly a rapidly emerging weed, serious enough to be a major ecosystem transformer. While some control measures have begun in Victoria, much remains to be done both there and especially in New South Wales where Coastal Saltmarsh is listed as an Endangered Ecological Community (NSW threatened Species Conservation Act) as well as in South Australia and Western Australia. A ban on the sale of the species by nurseries should be implemented immediately.

In 2010, Subtropical and Temperate Coastal Saltmarsh was nominated as threatened Australia-wide under the EPBC Act. Consequently, the relevant Draft Conservation Advice document was released for public comment in January 2013 (http://www.environment.gov.au/biodiversity/threatened/communities/-temperate-coastal-saltmarsh.html). The section on threats lists a number of invasive and potentially invasive species but not *Limonium hyblaeum*. This species clearly needs to be taken into account in the on-going assessment process.

There are possible threats from other alien *Limonium* species, 37 species of which are recorded as naturalized in Australia. Five species including *Limonium hyblaeum* have been recorded as weeds here (Randall 2007). Though none are treated as invasive, that is clearly now the case for *Limonium hyblaeum*. *Limonium perezii* (Stapf) Hubb. is both naturalized here and very widely promoted and sold in our nursery trade (e.g. Australian Broadcasting Commission 2011), is highly invasive in California (Weedwatch 2013) and clearly should be removed from sale here as quickly as possible.

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Reassessment of the invasion history of two species of *Cakile* (Brassicaceae) in Australia

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***Abstract*:** In this paper we revisit the invasion history of two species of *Cakile* in Australia. *Cakile edentula* subsp. *edentula* arrived in the mid 19th Century and spread into coastal strandline habitat from the southeast towards the west and to the north; *Cakile maritima* arrived in the late 19th Century and has replaced *Cakile edentula* over much of the range. While *Cakile edentula* is morphologically quite uniform, the great variation within *Cakile maritima* has confused field ecologists. Using herbarium records we update previous accounts of the spread of the species and report on field surveys that determined their current geographic overlap in Tasmania and in northern New South Wales/southern Queensland. We examine regional morphological variation within *Cakile maritima* using the national herbaria collections and variation within new population samples. We support previous interpretations that *Cakile maritima* has been introduced on more than one occasion from morphologically distinct races, resulting in regional variation within Australia and high variability within populations in the south-east. Western Australian populations appear distinct and probably did not initiate those in the east; we consider that eastern populations are likely to be a mix of *Cakile maritima* subsp. *maritima* from the Mediterranean and *Cakile maritima* subsp. *integrifolia* from Atlantic Europe. Although introgression from *Cakile edentula* into *Cakile maritima* cannot be discounted from our results, it is not required to explain the levels of variation in the latter species observed in Australia. *Cakile maritima* continues to spread southwards in Tasmania and northwards in NSW; in Queenland, a recent occurrence has proliferated in Moreton Bay, spreading slowly to the north but not appreciably southwards.

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Introduction

Two sea rockets (*Cakile* Mill., Brassicaceae) have spread around Australia's southern and eastern coastlines (Rodman 1986). They are mostly found close to the sea, typically, though not exclusively, at the top of the strand line and in the lower foredunes of sandy beaches. *Cakile edentula* (Bigelow) Hook., an annual self-fertilising species from eastern North America, has now probably completed its spread, whereas *Cakile maritima* Scop., an out-crosser from Europe and North Africa, is still spreading into areas previously occupied by *Cakile edentula*, replacing the latter species as it goes. Although invasive species arrivals are usually sequential, this rare example of complete replacement of one invader by another is notable in that it has also occurred in south-western North America (Barbour & Rodman 1970) and New Zealand (Cousens & Cousens 2011).

Despite their local abundance, the species are seldom controlled by managers as their impacts are perceived as slight. Although they form small incipient dunes, their impact on larger scale coastal geomorphology is probably insignificant; they compete with few native plant species (southern Australia has a very limited native strand flora); they have both negative and positive impacts on native and

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exotic birds and insects, but these have never been quantified; and although they are obvious to beach-goers, they do not significantly impact on their enjoyment (Cousens et al. 2013).

The invasions of *Cakile* in Australia have been described previously by Rodman (1986), but their spread has been rapid and further changes in their distributions have occurred in the last quarter of a century. The advent of databases has also meant that further records important in the invasion chronology, but unavailable to Rodman, have come to light. Significantly, there remains considerable confusion amongst ecologists about the identification of the taxa in Australia. Specimens are frequently incorrectly identified and thus the progress of the invasions cannot be charted by simply consulting databases such as Australia's Virtual Herbarium, databases of State Government departments or local species lists. Adding to the confusion, it has been claimed that the high level of morphological variation in Australian *Cakile maritima* compared to North America (where it is also exotic) has arisen from hybridisation and introgression from *Cakile edentula* in this country (Cody & Cody 2004); statements have also been made on web sites that hybrids are common and often predominate (Queensland Government 2012). The alternative explanation of the morphological variation, multiple introductions from the native range, has not been considered. Repeated introductions may have given rise to regional variation in the species as well as to variability within some regions.

The aim of this study was to better document the invasion history of the species in Australia by: (a) confirming the identity of available herbarium specimens in all major Australian herbaria, through reference to variation in the species within their native ranges; (b) using the resulting confirmed herbarium databases to establish times of introduction to, and disappearance from, different regions of the country; (c) surveying areas believed to be at the leading edges of the *Cakile maritima* invasion, thus establishing the current extent of the invasion; and (d) examining morphological variation within and between sites across the country to see whether this provides additional clues.

Methods

The species

Before describing the research methods, we briefly review the taxonomy and distribution of the two species overseas. This will help to explain the measurements that we have made and aid in their interpretation. Both species have fruits divided into two single-seeded sections (though either the proximal or both proximal and distal may not develop); the distal section disarticulates readily as it ripens while the proximal remains on the maternal parent. As well as the transverse abscission zone between the proximal and distal fruit segments, an abscission zone can be seen running from top to bottom around the fruit (the replum) along which each segment later splits to release its seed or when the seedling emerges. Henceforth, for ease of discussion, it is assumed that this replum is lateral when examining a fruit. The two species and their subspecies can be distinguished most readily by fruit and leaf characters and this is used in most keys. The species also differ in various aspects of flower morphology (Rodman 1974). For example, *Cakile edentula* mean petal width is only half that of *Cakile maritima* (Rodman 1974; Cody & Cody 2004). Although most Australian State and national floras give ranges of petal length for the species that would appear to be of diagnostic value, petal lengths of the two species recorded in their native distributions overlap to some extent (Rodman 1974; Tutin *et al.* 1993; Rich 1992), as do the lengths of the lamina of the open flowers (the petal's "limb" – Rich 1992) in North America (Cody & Cody 2004). Our own unpublished measurements in Australia also suggest that petal lengths are of minor taxonomic use.

Two subspecies of *Cakile edentula* are usually recognised in its native range: *harperi* (Small) Rodman and *edentula* (Rodman 1974) [though *Cakile arctica* Pobed. is sometimes referred to as *Cakile edentula* subsp. *islandica* (Tutin et al. 1993)]. Subspecies *edentula* has two varieties, *edentula* and *lacustris* Fernald. Australian material has previously been ascribed to *Cakile edentula* subsp. *edentula* var. *edentula*, which has a native distribution from Labrador to North Carolina. There is a distinct narrow waist between the two fruit segments in this subspecies (Fig 1a). The lower segment is circular in transverse section and is somewhat narrowed at both ends, forming an elongated barrel shape. The upper segment is globular, with an elongated "beak" that is commonly dorsiventrally flattened and the apex is often emarginate and a dark red/purple. Where the proximal and distal fruit segments separate, the abscission scar is virtually flat or with a few slight projections, but never saddle-like (as in *Cakile maritima*). The leaves are usually coarsely serrate to incised (Fig 2); however, those formed early or late in plant development may merely have a few marginal notches.

Cakile maritima is highly variable in its native range. The presence of lateral "horns" or "spurs" on the proximal fruit segment (Fig. 1b) is considered diagnostic for the species (Rodman 1974; Hewson 1982), but these projections vary in size and form geographically and within populations: Ball (1964) comments that the spurs are "small, often absent" along the Atlantic coast of Europe (Fig 1g) to over 1 mm long in the Mediterranean (Fig. 1h) and Baltic (see also Castroviejo 1996). There are clear geographic trends in fruit morphology that appear to undergo rapid transitions in parts of the range (supported by molecular studies: Clausing *et al.* 2000; Kadereit *et al.* 2005), but the places to draw the lines (both geographically and morphologically) and how many lines to draw are still open to debate. Leaf margins in the species also vary from entire to coarsely serrate to pinnatisect to almost bipinnatisect (Fig. 3) according to geography (Davy *et al.* 2006; Rodman 1974; Tutin *et al.* 1993), but they also vary within a region or site (Ross-Craig 1958, Gandour *et al.* 2008, Mouterde 1970, Ciccarelli 2010).

Infra-specific taxonomy in *Cakile maritima* is based primarily on fruit and leaf shapes (Pobedimova 1963; Ball 1964; Rodman 1974), but descriptions of the subspecies recognise the existence of considerable overlap in both traits. The current convention in Europe (Marhold 2011, which we use in this paper) recognises four regional subspecies: subsp. *maritima* in the Mediterranean; subsp *baltica* (Rouy & Foucaud) P.W. Ball in the Baltic; subsp. *integrifolia* (Hornem.) Greuter & Burdet on the Atlantic coasts; and subsp. *euxina* (Pobed.) Nyárády in the Black Sea [but note that, confusingly, in Flora Europaea (Tutin *et al.* 1993) subsp. *maritima* is the Atlantic subspecies and subsp. *aegyptiaca* is the Mediterranean subspecies]. Fruits can apparently be distinguished on the basis of the shape of the proximal fruit segment viewed side-on after the distal segment has disarticulated and by the length of the spurs (Ball 1964). Leaf shape diagnostics are more confused. While plants of subsp. *maritima* are most commonly pinnatisect, some plants have entire margins (Gandour *et al.* 2008, Ciccarelli 2010, and have been referred to as var. *latifolia* (Mouterde 1970) or var. *integrifolia* on various herbarium specimens: R.D. Cousens, unpublished), and others are bipinnatisect (Davy *et al.* 2006 and our own observations) – even though Flora Europaea (Tutin *et al.* 1993) confines bipinnatisect leaves to subsp. *euxina* and *baltica*. Despite its name, leaves of subsp. *integrifolia* may have entire or serrated margins, or may be deeply lobed (Ross-Craig 1958).

In addition to Australia, *Cakile edentula* has spread to the Pacific coast of North America, New Zealand (including the Chatham Islands), Japan and the Azores (floras published in the invaded ranges rarely identify the *Cakile* subspecies); var. *edentula* has spread from the Atlantic into the Great Lakes. *Cakile maritima* has colonised Australia, New Zealand (including the Kermadec Islands), New Caledonia, the Caspian coast of Iran, eastern South America and the Pacific coast of North America; it has been recorded in a few locations on the east coast of the USA. Herbarium specimens in Australia may often be labelled subsp. *maritima* or subsp. *baltica* (apparently following Rodman's recognition of three subspecies, where subsp. *maritima* extends from the North Atlantic to the Mediterranean).

Confirmation of specimen identification

We accessed all available specimens in the major Australian herbaria (AD, BRI, CANB, HO, MEL, NSW, PERTH) (herbarium codes follow http://www.sweetgum.nybg.org/ih/) except the Australian Tropical Herbarium (CNS) and the Northern Territory Herbarium (DNA) as *Cakile* does not occur in tropical Australia. Many specimens had only fruits, some had no flowers and others no leaves. Where present, we

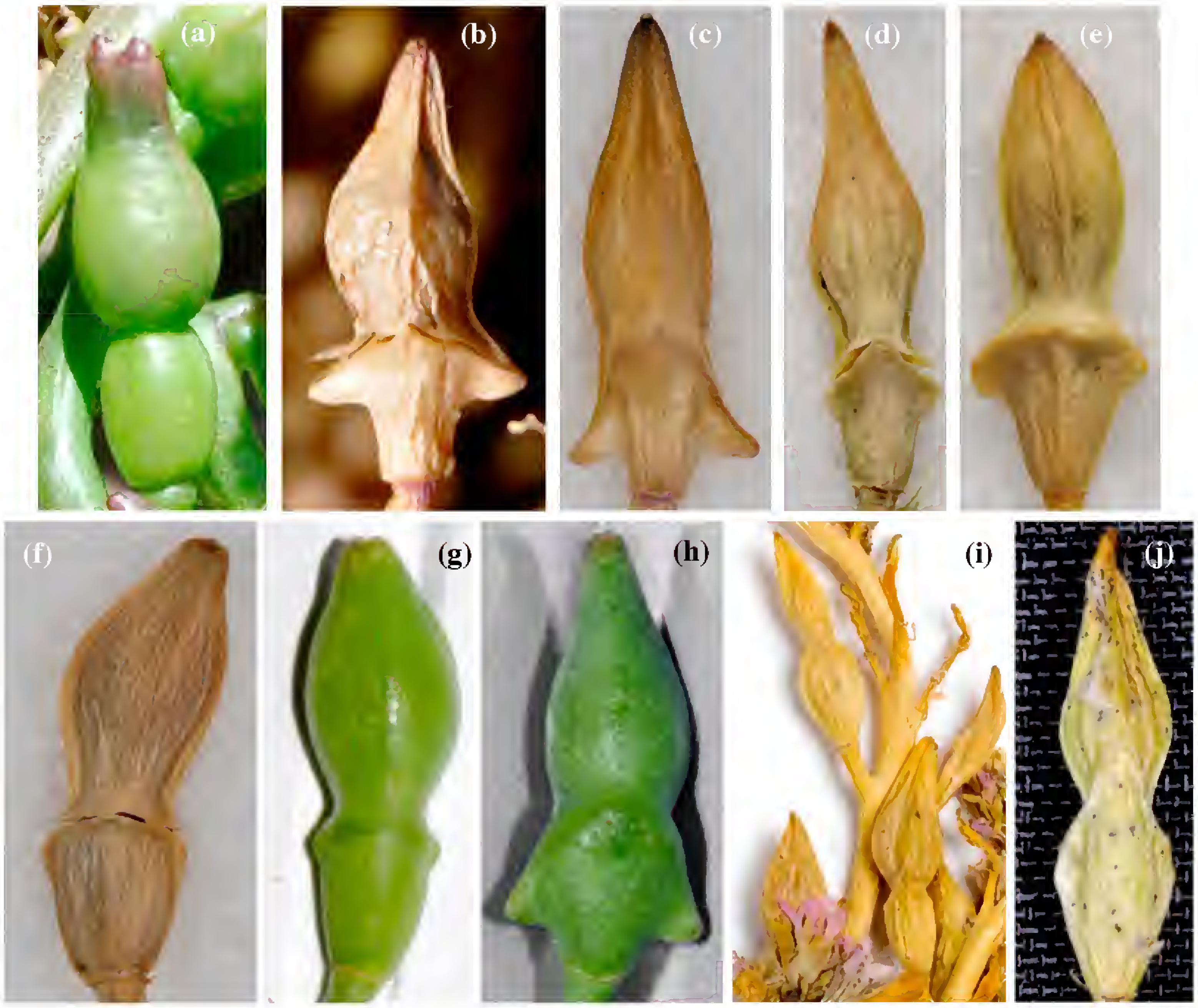

Fig. 1. Fruit shape variation in *Cakile*: (a) *Cakile edentula* subsp. *edentula* from Bolton's Beach, Tasmania, (b) *Cakile maritima* from Sulphur Creek, Tasmania, (c,d) *Cakile maritima* from West Lakes Shore, South Australia, (e) *Cakile maritima* from Applecross, Western Australia, (f) *Cakile maritima* from Golden Bay, Western Australia, (g) *Cakile maritima* subsp. *integrifolia* from Cantabria, northern Spain, (h) *Cakile maritima* subsp. *maritima* from Torremolinos, southern Spain, (i,j) putative hybrids from Sloping Main, Tasmania (Cousens n.c., HO565167). Specimens of Australian *Cakile maritima* were chosen to represent the range of variation in Australia rather than to be typical of each site. Photographs are taken such that the replum runs round the circumference.

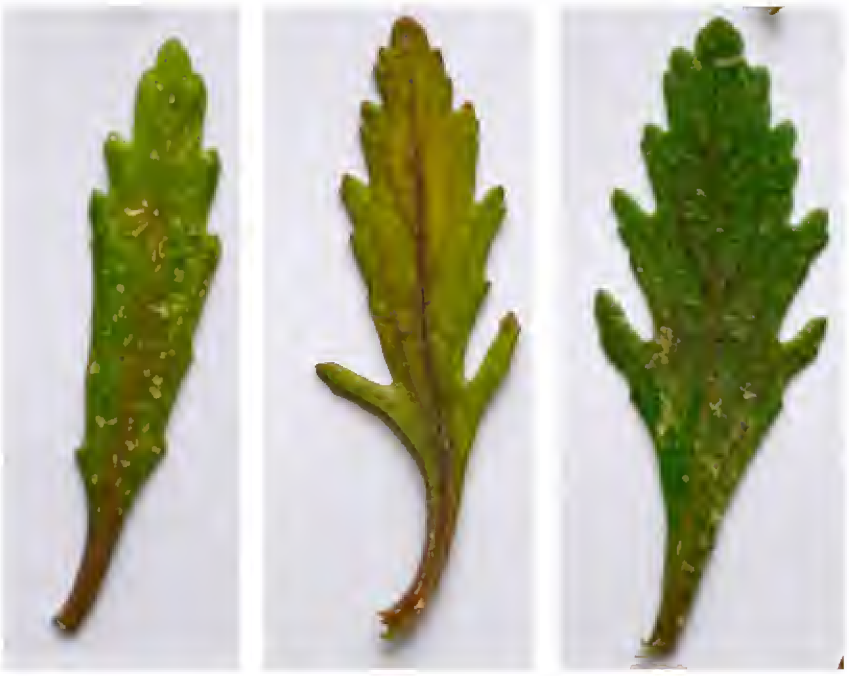

Fig. 2. Examples of leaf shapes of *Cakile edentula* from Tasmania.

examined fruit shapes, paying particular attention to shapes of both fruit segments and the abscission scar left after the distal fruit had separated. Floral features were examined in detail only where identification was difficult to ascertain from fruit and leaf shapes.

Reference material describing the species was obtained from a wide range of sources. The herbarium collection at KEW was examined, covering most of the native range of *Cakile maritima* and parts of the native range of *Cakile edentula*. Key publications consulted about infraspecific variation included Ball (1964), Rodman (1974) and Davy *et al.* (2006). Additional taxonomic information on *Cakile maritima* was obtained from Tutin *et al.* (1993) and Euro+Med Plantbase (Marhold 2011), as well as through personal communication with James Rodman. We also consulted a wide range of regional pictorial floras and scientific papers depicting morphological variation within the native ranges (e.g. Gandour *et al.* 2008; Ciccarelli *et al.* 2010). Finally, we surveyed photographic images and line drawings obtained through Google™ searches.

Invasion history

Having corrected the determinations of specimens where necessary, we examined the databases supplied by each herbarium. For each State, as well as for distinct geographic regions, we identified the first and last collections of each species. At PERTH and AD we accessed letters that were relevant to the invasion history and at AD we were provided with previously unlabelled specimens.

To determine current range limits more accurately, we surveyed beaches in regions encompassing the apparent areas of species overlap, in Tasmania in February 2012 and 2013 and in northern NSW/southern Queensland in October 2012. Beaches were chosen according to accessibility, previous herbarium records, previous surveys (P.C. Heyligers, unpublished data) and available time. At each beach, sufficient distance was walked until both species were recorded or until it seemed unlikely that a species was present (typically around 500 m).

Morphological variation within and between regions and populations

Each of the 845 confirmed herbarium specimens of *Cakile maritima* was, where possible, assessed for leaf shape (using the scale in Fig. 3) and the shape of the proximal fruit segment when viewed at 90° to the replum (Fig. 4). Our ordinal leaf shape scale differs somewhat from those of Cody & Cody (2004) and Gandour *et al.* (2008) as some of their categories were difficult to distinguish and the correct order of their shapes is debatable. Since the shape of leaves changes during development, with young leaves and uppermost stem leaves being the least lobed, we scored the leaf on each plant having the highest value on the shape scale. Our fruit shape scales also differed from those authors, since ours is based on photographs of actual fruits. Fruits were only scored if they were fully grown and the proximal segment had developed; where there was variation among fruits, we scored the one

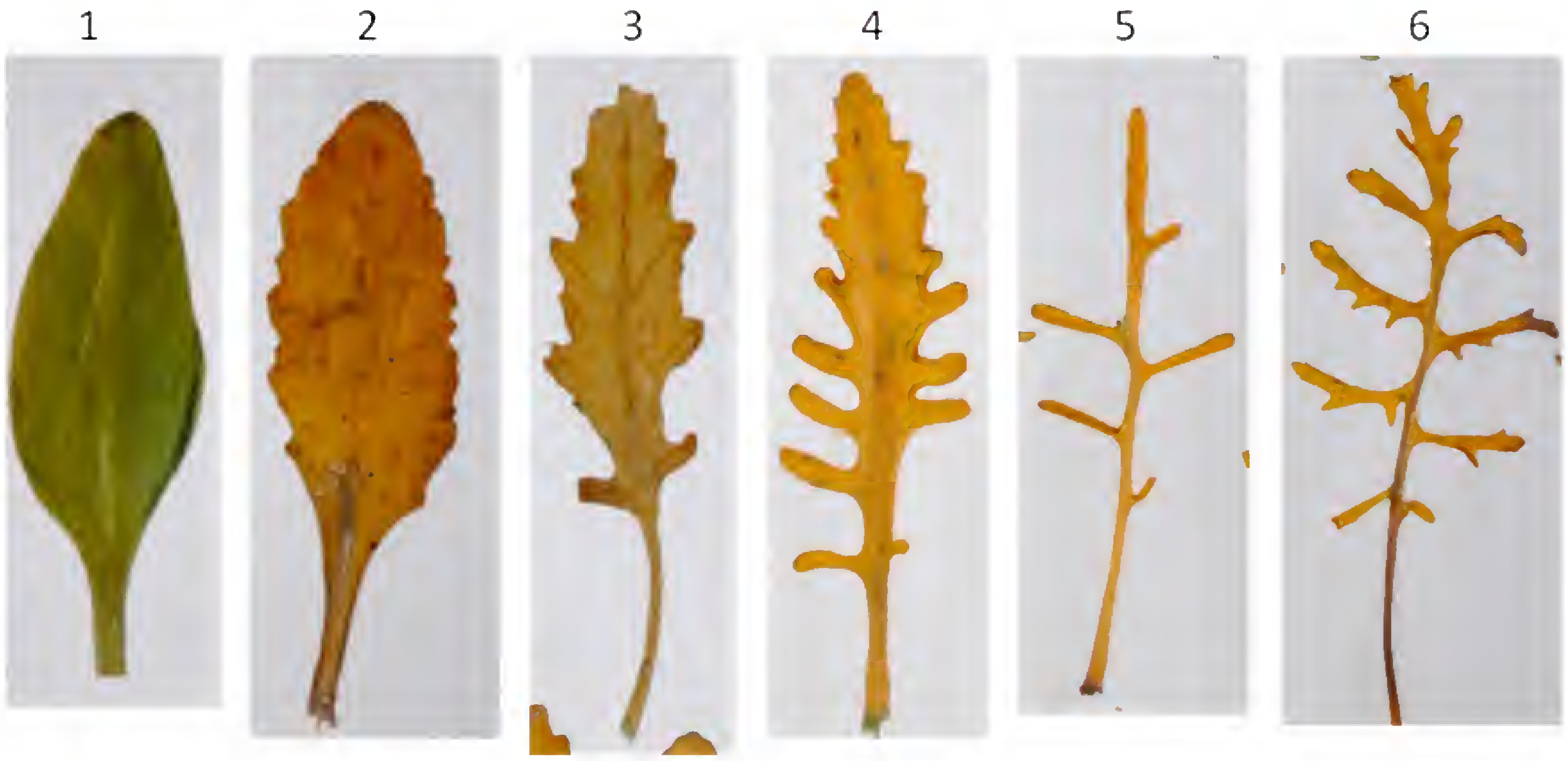

Fig. 3. Range of leaf shapes of *Cakile maritima* in Australia. Numbers indicate classes used in morphological analysis.

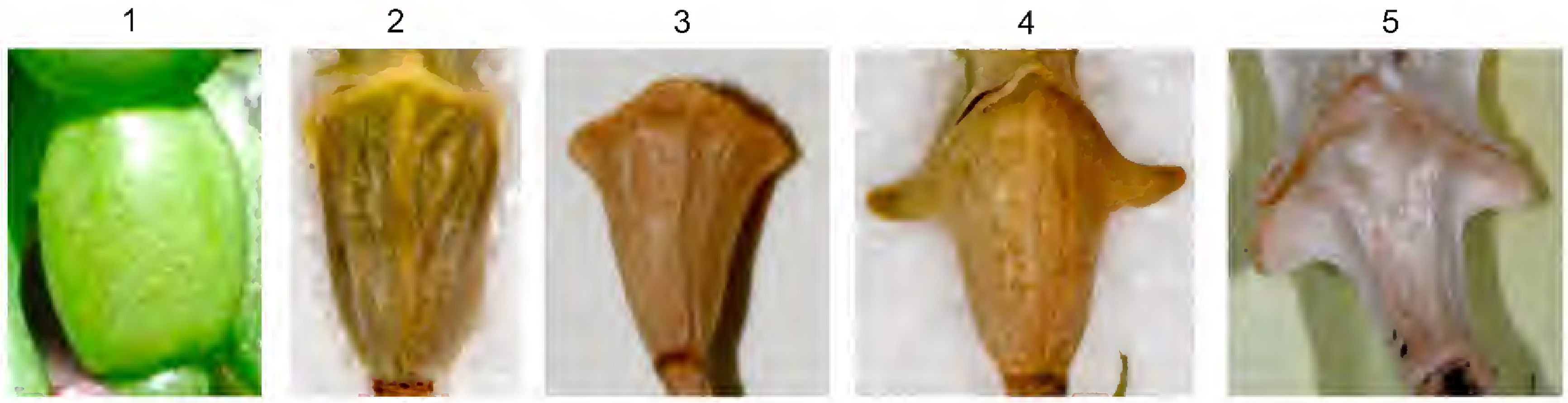

Fig. 4. Range of shapes of proximal fruit segment found in Australian *Cakile*. Left (1) is typical of *Cakile edentula*; others (2-5) are *Cakile maritima*.

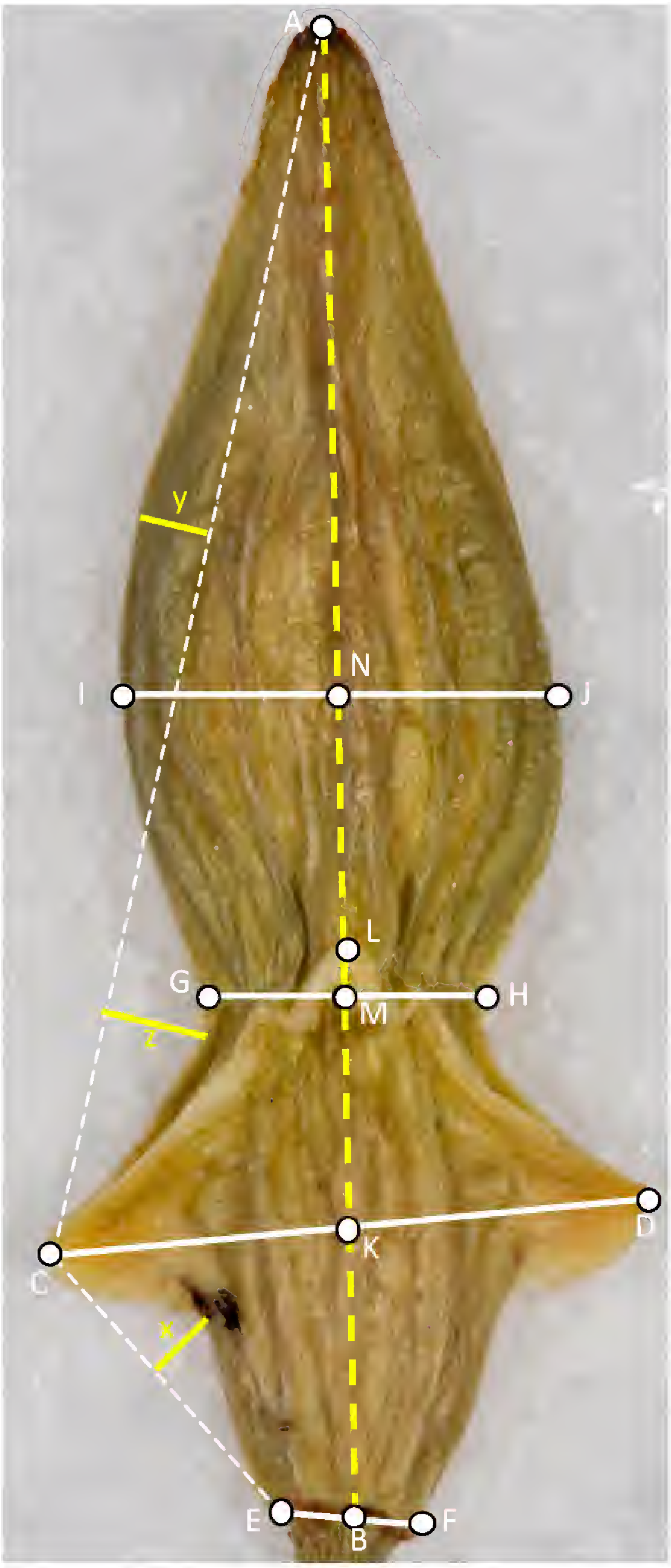

Fig. 5. *Cakile maritima* fruit, showing 'landmarks' and distances recorded in morphometric study.

with the highest value on the shape scale. Relative frequency distributions of leaf and fruit attributes were constructed on a State basis; collections of *Cakile maritima* from Queensland were included with NSW due to small sample size.

We also collected samples of leaves and fruits from fifty plants at each of three sites in Western Australia (Applecross, Golden Bay and Woodman's Point), one site in each of South Australia (West Lakes Shore, also sampled by Cody & Cody 2004), Victoria (Lakes Entrance) and Lord Howe Island (Lagoon Beach), and two sites in Tasmania (Marion Bay and Burnie) (Table 1). At each site, the nearest plant was sampled at 5 m intervals along the shore. A single ripe, intact fruit with a developed proximal fruit section and the leaf with the greatest degree of lobing were collected. Leaves were scored using Figure 3. Fifty plants were also scored for leaf shape at Beachmere, north of Brisbane, Queensland. Fruits were air-dried, then photographed at 90° to the replum. Attributes of all fruits were measured on the digital images of 19 random fruits using tpsDig Version 2.16 (Stony Brook Morphometrics, USA). Traits measured were CD, EF, GH, IJ, KB, LB, MB, NB, x, y, and z (Fig. 5); these were all standardised by dividing by total fruit length (AB). Four derived variables were also calculated: CD/LB, CD/EF, x/CD and (LB–KB)/CD. We attempted to obtain fruit measurements from herbarium specimens from the native range (representing *Cakile maritima* subsp. *maritima*, *baltica* and *integrifolia*), but fruits were rarely mature, intact and lying in the appropriate plane. The opportunity arose to obtain photographs of a small number of fresh fruits from single sites on the Atlantic (14 fruits) and Mediterranean coasts of Spain (four fruits) representing part of the variation within *Cakile m. integrifolia* and *Cakile m. maritima* respectively). The most fully developed, intact fruit was collected from every mature plant on the beach, but these were photographed fresh rather than dried (and thus potentially affecting morphometric measurements).

Frequency distributions of leaf and proximal fruit segment shapes were analysed using generalized linear models (multinomial distribution with cumulative logit link in SAS); chi-square tests were used to compare States or locations. Morphometric data were analysed using Principal Components Analysis in SAS.

Table 1. Locations of *Cakile* collections for morphometric analysis.

State	Location	Latitude (S)	Longitude (E)
Western Australia	Applecross	32° 0.7’	115° 49.8’
Western Australia	Golden Bay	32° 25.9’	115° 45.0’
Western Australia	Woodman’s Point	32° 7.5’	115° 45.5’
South Australia	West Lakes Shore	34° 52.3’	138° 28.8’
Victoria	Lakes Entrance	37° 52.8’	148° 0.4’
New South Wales	Lord Howe Island	31° 31.8’	159° 4.0’
Tasmania	Marion Bay	42° 50.2’	147° 52.6’
Tasmania	Burnie	41° 2.9’	145° 54.1’

Results

Confirmation of herbarium specimen identification

The great majority of specimens fell within the range of variation documented for each of the two species in their native ranges. Thus, attribution to a species was mostly straightforward. We altered the determinations of a small number of specimens in most herbaria, usually from *Cakile edentula* to *Cakile maritima*.

Our observations supported the classification of Australian *Cakile edentula* as subsp. *edentula*, notably with respect to the constriction between the proximal and distal fruit segments. Within Australian specimens of *Cakile maritima*, we found the complete range of leaf shapes exhibited by plants within the native range of the species (see also Heyligers 1989; Davy *et al.* 2004); the same was true for proximal fruit segments, which ranged from hastate with wide “horns” to having almost no horns at all. It was usually impossible to ascribe a particular specimen to a subspecies using the guide published by Ball (1964) or the photographs in Rodman (1974): a proportion of specimens had the strongly deflexed horns depicted for subsp. *maritima* (Ball’s *aegyptiaca*), but most horns were not deflexed and were of intermediate size and thus could correspond to several of Ball’s drawings. Few specimens had a flat top to the abscission scar (when viewed along the plane of the replum), as depicted by Ball for his Baltic and Atlantic subspecies, but the shape was also seldom the smooth convex curve shown for the other subspecies. Thus we were unable to confirm the identification of specimens in herbaria labelled *Cakile maritima* subsp. *baltica* (or indeed most labelled *Cakile maritima* subsp. *maritima*).

Just a few specimens were difficult to allocate confidently to either species. Some of these had fruit characters suggesting that they were intermediates. The overlap in leaf shapes of the two species and the great range in *Cakile maritima* fruit morphology means that the identification of hybrids must be extremely uncertain. We identified just 13 possible hybrids, but several of these lacked many distal fruit segments and leaves. Specimens collected from regions and periods in which the species were sympatric, and with unusual shaped fruits, include Cleland s.n. (AD966040594), Gray 6652 (CANB349172, 349173), Heyligers 79163, 79192 (CANB291551, 291552, 291326), Melville 2231 (NSW642911), Cousens s.n. (HO565167; Fig. 1i,j).

Invasion history

The arrival and spread of *Cakile edentula*. There are early records of *Cakile edentula* in southern Australia from the 1860s and 1870s, and although it is tempting to deduce that the first record represents the first region of entry and that the species subsequently spread from there (Rodman 1986; Sauer 1988) such a chronology is by no means certain since collection intensity at the time was very low. *Cakile edentula* was first collected on Phillip Island, Victoria by F. Mueller in 1863 (s.n., MEL1004009): he noted “*known there wild since 20 years*”. The first New South Wales specimen is from Manly Beach in 1870 (Woolls s.n., MEL1004032), while the first record from Tasmania was on the north coast near Circular Head (Stanley) in 1875 (Mueller s.n., MEL1004023). It was in South Australia by 1881 (Destrees Bay, Kangaroo Island: Tate s.n., AD97324157).

There is some doubt about the eventual limit of *Cakile edentula*’s westwards spread. It had established at The Head of the Bight by 1955 (Cleland s.n., AD97229257) and near Eucla by 1962 (Phillips s.n., NSW131654). A sample from Esperance Bay in 1952 (Carpenter s.n., PERTH 3236900) lacking distal fruit segments appears also to be *Cakile edentula* but a sample collected from Mandurah, south of Perth, in 1970 by H. Salasoo (4052, NSW120069, cited by Rodman 1986) was incorrectly identified. Therefore, although *Cakile edentula* spread along the Bight, there is no evidence that it has ever occurred further west than Esperance.

On the east coast, *Cakile edentula* spread northwards, though a paucity of samples from NSW makes its chronology uncertain. It was in Queensland by 1922 (Stradbroke Island: White 1680, BRI278332) and had reached Heron Island by 1958 (Gillham s.n., BRI278327). The most northerly records are Mackay (1993: Champion 878, BRI621568) and Bushy Island (1989: Walker s.n., BRI457562). Surveys further north are needed to confirm the limits of distribution (the small, highly ephemeral populations – Heyligers 2007 – make surveys difficult). *Cakile edentula* was present on Lord Howe Island by 1898 (Pickard, 1984; King s.n., NSW104038;). In Tasmania, *Cakile edentula* was at Port Davey on the west coast by 1893 and Hobart by 1900.

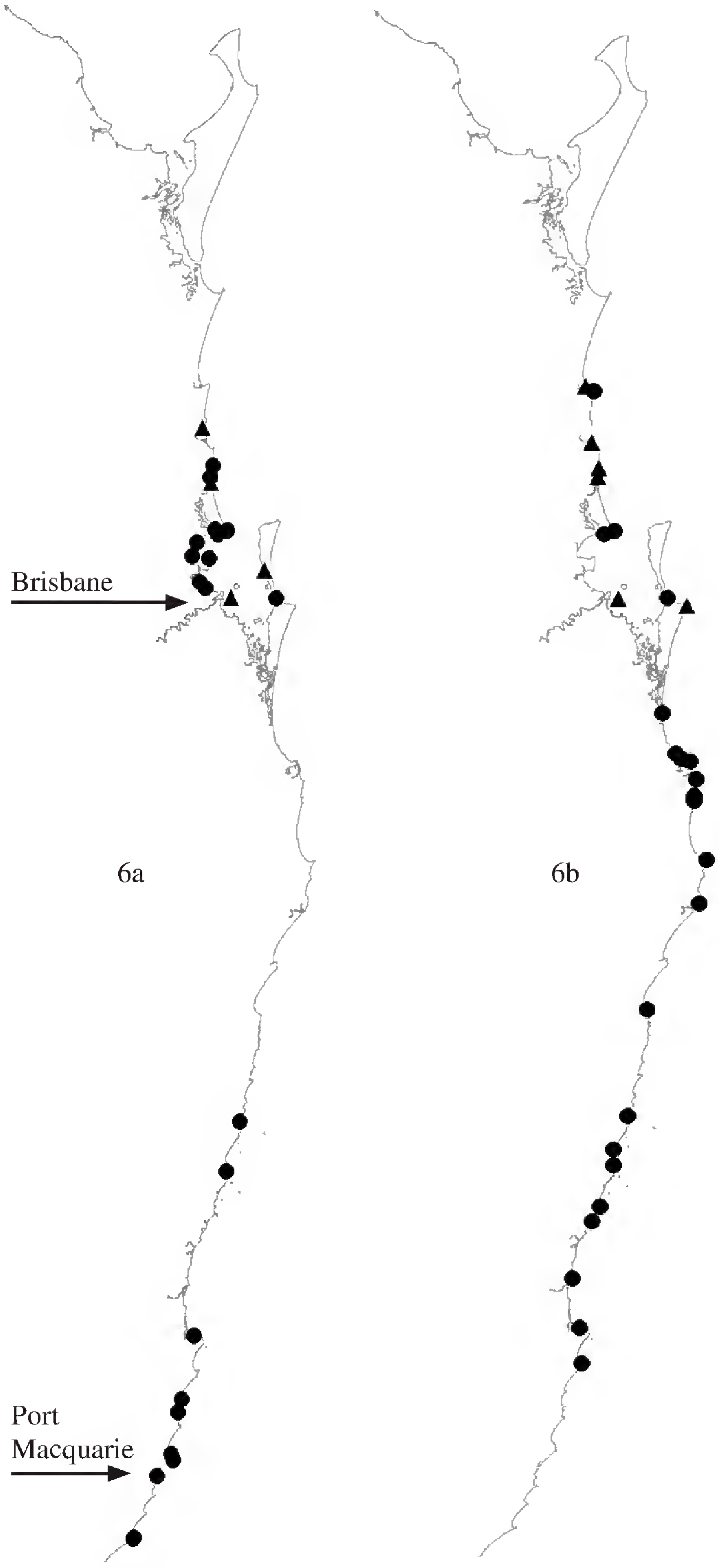

Fig. 6. Presence data (solid circles) from survey of northern NSW and southern Queensland in November 2012. **(a)** *Cakile maritima*, **(b)** *Cakile edentula*. Triangles are herbarium records and unpublished observations by PC Heyligers, both since 2000.

The arrival and spread of *Cakile maritima*. *Cakile maritima* first appeared in Western Australia (Fremantle, 1897: Helms s.n., PERTH3236757). It had reached Albany on the south coast by 1901 (Goadby 142, PERTH3236749). The first collections from the eastern States were from South Australia in 1918, from the coast (Adelaide, unnamed AD254851) and from about 100 km inland (Kybybolite, Andrew s.n., AD97227097). Although it is possible that the latter may be a labelling error (P.C. Heyligers, pers. comm.), there is correspondence (but no other specimens) in the State Herbarium of South Australia concerning *Cakile* in that region: a weed adviser from the Department of Agriculture writing in 1949 states that a sample from a sandy ridge in a field near Pinnaroo had been identified as *Cakile maritima*. There is also a more recent inland collection, from Broken Hill (1977: RJS 2045, NSW642909) on an old zinc mine spoil heap.

Cakile maritima was first collected in Victoria at Beaumaris, a Melbourne suburb, in 1922 (Tadgell s.n., MEL1003990). It was not recorded until 1968 in NSW, at Nadgee River in the south, but collections soon after that (e.g. Woy Woy 1969: McBarron 17663, NSW642907) suggest that it may already have been widespread in southern NSW by that time. The species was first collected on Lord Howe Island in 1992 (Swarbrick 10492, BRI589916). Heyligers (pers. comm.) found *Cakile maritima* as far north as Port Macquarie in 1998, while in our survey in November 2012 (Fig. 6) the most northerly site we located for *Cakile maritima* was Wooli Beach (about 180 km further north; note that this beach was also visited in Heyligers' survey but found to have only *Cakile edentula*). In 2002, *Cakile maritima* was found in southern Queensland (Bribie Island: Heyligers s.n., BRI558626, 558627) and has since been collected from several beaches in that region, as far north as Coolum. In 2012, all mainland sandy beaches in the Moreton Bay area contained *Cakile maritima*; in 2011 both species were present on North Stradbroke Island. Although *Cakile maritima* was also common at Golden Beach, Caloundra in 2012, it was only found at one site further north (Currimundi Lake, south of Coolum) in that survey. Although it seems plausible that the mid-NSW invasion front leapfrogged the northern NSW coast to arrive in Moreton Bay, we note that there are morphological differences between populations in NSW and Queensland. Those in Moreton Bay almost (but not quite) exclusively have pinnatisect leaves (leaf type 5, Fig. 3) and always have distinct horns on the fruits (also noted previously by Heyligers); the majority of plants in mid-NSW had serrate or slightly lobed leaves (leaf types 2–4, Fig. 3) and the fruits have a range of horn lengths.

In the Bass Strait, *Cakile maritima* was collected from Deal Island in 1957, Flinders Island in 1972 and King Island in 1979. The first record for mainland Tasmania is Sullivan's Cove, Hobart in 1963 (Pearson 581, MEL577437), although it does not appear to have persisted in that part of the State. The first record in northern Tasmania was 1979 and on the east coast was 1987. An extensive survey of western Tasmanian beaches in the mid-1980s found *Cakile maritima* on most beaches (along with *Cakile edentula*) (Fig. 7c). By February 2012, *Cakile maritima* was as far south as the east coast of Bruny Island (Fig. 7a), with only beaches around the Derwent River and D'Entrecasteaux Channel yet to be invaded.

The demise of Cakile edentula.

The last *Cakile edentula* collection known from South Australia was in 1983 (in the Bight: Toelken 7635, AD98415058). It appears to have persisted longer in the Bight (at least 75 years after *Cakile maritima* was first recorded in South Australia) than further east in the State (where the last *Cakile edentula* specimens were collected in 1936). The first *Cakile edentula* specimen collected in the Bight (here defined as between Eyre, Western Australia and Fowler's Bay, South Australia) was 1955 (Cleland s.n., AD97229257) and the last 1983; the first *Cakile maritima* collection from that region dates from 1984 (Downing 1006, PERTH3279979) and all *Cakile* specimens from that date onwards have been of this species. A more systematic field survey might show that *Cakile edentula* still exists in this remote region. Possible hybrids have been reported from the eastern side of the Bight in 1979 (Heyligers 79163, 79192, CANB291551, 291552, 291326).

The most recent collection of *Cakile edentula* from Victoria dates from 1986, from the far east of the State (Thurra River: Heyligers 86035, CANB403745) (P.C. Heyligers, pers. comm., also reports it nearby at Wingan in 2000). The most recent specimen from Victoria west of Melbourne dates from 1953 (Melville 3191, MEL520919). In the mid-1980s both species could be found together in southern NSW (Heyligers, 1984), but this no longer appears to be the case. The southern limit of *Cakile edentula* in the late 1990s was Forster (P.C. Heyligers, unpublished data), while the two species were sympatric on several beaches between there and Port Macquarie (a range overlap of about 100 km). In November 2012, the most southerly *Cakile edentula* found was at Hat Head (Fig. 6), 160 km north of Forster (i.e. an estimated range contraction of 12 km per year), with a sympatric zone of perhaps 120 km. It should be noted that within the sympatric zone, some beaches only had *Cakile edentula* present and the furthest northwards "satellite" populations of *Cakile maritima* were a long way apart. Off the NSW coast, all collections of *Cakile* on Lord Howe Island were *Cakile edentula* until 1978; all collections since 1992 have been *Cakile maritima* and in a detailed survey in November 2011 we failed to locate any remaining *Cakile edentula*.

In Queensland, *Cakile maritima* has spread to the north of Moreton Bay (though it is still uncommon north of Golden Beach, Caloundra), but apparently not to the south. Within Moreton Bay, most beaches (including those at which *Cakile edentula* has been collected in the past) in November 2012 contained only *Cakile maritima*, while on the western side of Bribie Island *Cakile edentula* is now very much less abundant

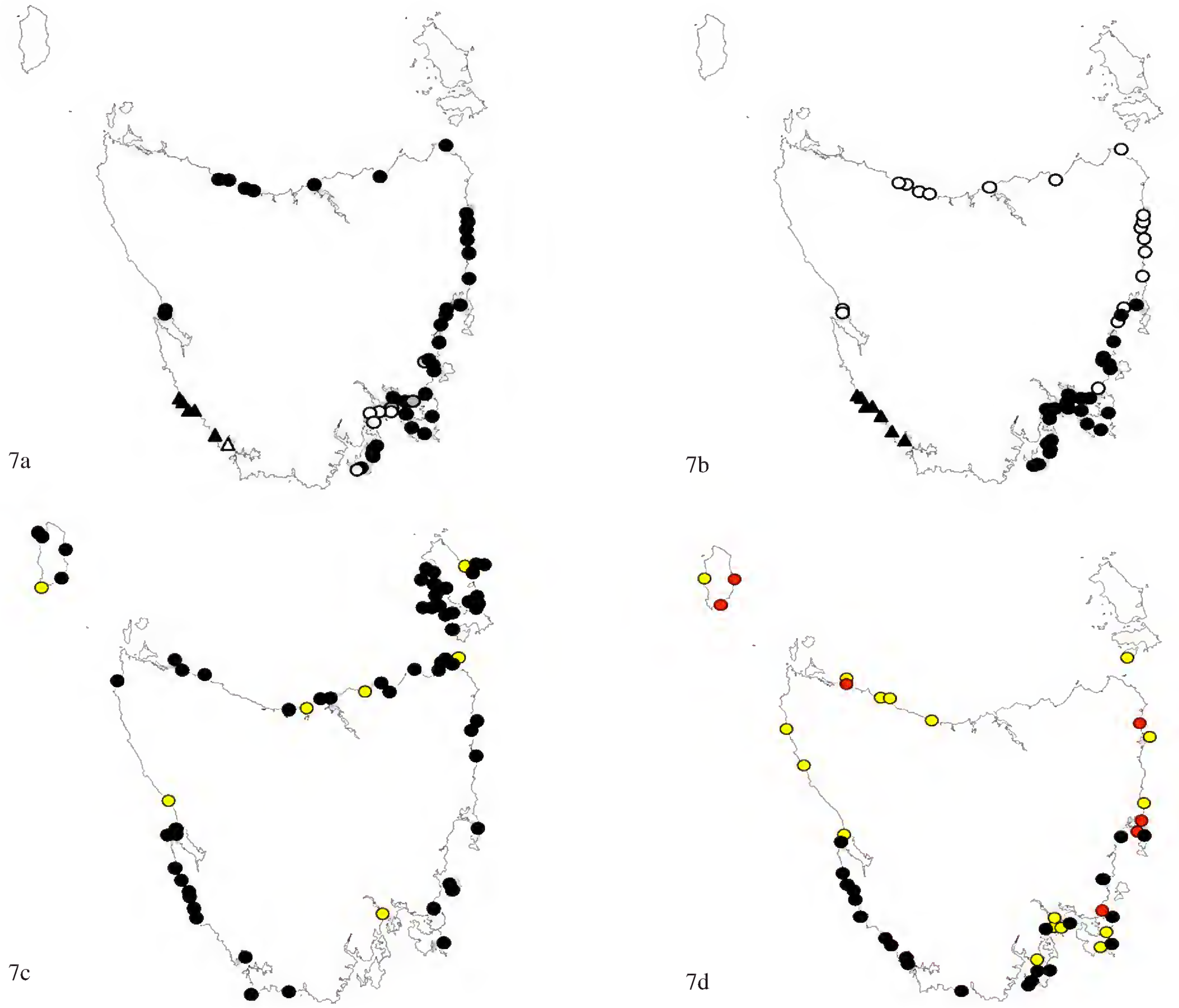

Fig. 7. (a) *Cakile maritima*, (b) *Cakile edentula* distribution data from survey of Tasmania in February 2012 (solid circles); (c) *Cakile maritima*, (d) *Cakile edentula* specimens in herbaria. Unfilled symbols in (a) and (b) indicate beaches sampled where *Cakile* was present but that species was not found; grey circle indicates possible presence (poor specimens with neither flowers or fruits); triangles are based on photographs by J. Marsden-Smedley. In (c) and (d) yellow circles are pre-1982; red circles indicate unpublished 1993 records of PC Heyligers.

than *Cakile maritima* (the reverse of the situation reported by Heyligers in 2002/3).

In Tasmania, *Cakile edentula* now seems to have disappeared from all but the south-east corner of the State and the west coast. The most recent *Cakile edentula* herbarium specimen from the north coast of Tasmania dates from 1949, although P. C. Heyligers (pers. comm.) recorded a few plants near Stanley and two plants on King Island in 1993. On the east coast of the State, the species was still found as far north as St Helens in 1993 (P.C. Heyligers, pers. comm.), although the most recent herbarium specimen north of the Freycinet Peninsula was Bicheno in 1981. In a survey in February 2012 (Fig. 7), we were unable to find *Cakile edentula* except from the Freycinet Peninsula southwards. The two species were sympatric on most beaches from there southwards to the east coast of Bruny Island; a few likely hybrids were found at Raspin's Beach, Orford and at Sloping Main (Tasman Peninsula) but at all other beaches the species were usually easily distinguished. Only *Cakile edentula* was found on the west side of the South Arm Peninsula and at Cloudy Bay, Bruny Island in 2012. However, we found one *Cakile maritima* and two possible hybrids at Cloudy Bay in 2013, and several *Cakile maritima* and hybrids at Seven Mile Beach. In 2012, both species were still found on beaches in the south-west (J. Marsden-Smedley pers. comm. and photographs) although in most cases (but not all) *Cakile maritima* was more abundant. Thus probably only the area around the D'Entrecasteaux Channel and the Derwent River remain invaded only by *Cakile edentula*.

Morphological variation within and between regions and populations

All leaf types were present in herbarium collections from all regions (including Western Australia, where *Cakile edentula* has never been recorded west of Esperance). There were significant differences (p<0.0001) in the leaf shapes between regions (Fig. 8). South Australia and Western Australia had higher proportions of pinnatisect leaves (Type 5) than other States, while Western Australia had a distinctly greater proportion of bipinnatisect leaves (Type 6) than other States. Leaf type 4 was at a lower frequency than types 3 and 5 in all States. There were also significant differences (p<0.0001) in

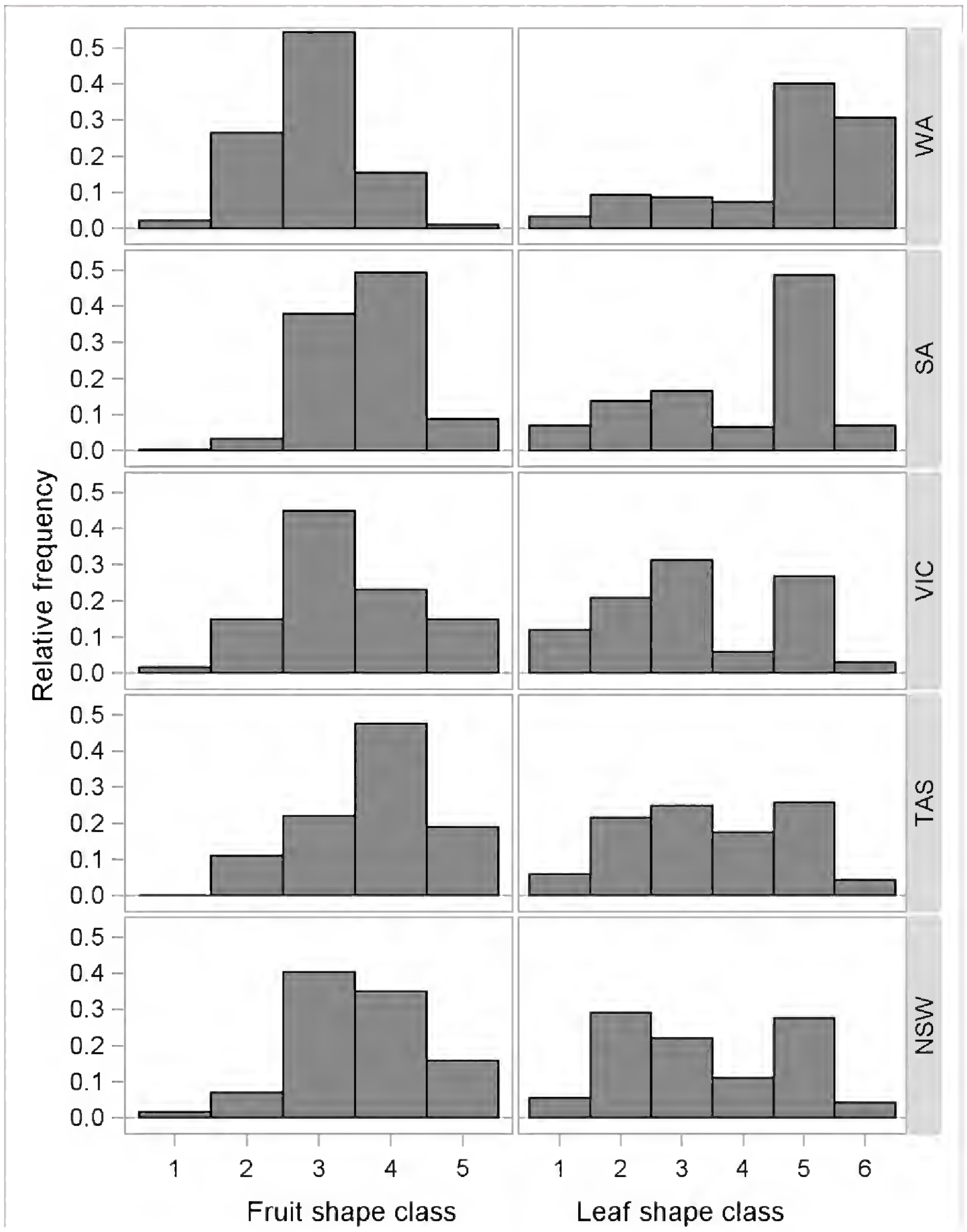

Fig. 8. Relative frequencies of shapes of *Cakile maritima* basal fruit segments and leaves represented within major Australian herbaria, according to the State in which samples were collected. See Figs. 3 and 4 for shape category scales.

the frequencies of basal fruit segment shapes between States (Fig. 8). Shape 3, with only slightly developed horns, was least prevalent in Tasmania, while the greatest frequencies of shape 4 were in South Australia and Tasmania.

Leaf and fruit shapes in all the sampled populations were within the range of variation of *Cakile maritima* expected from its home range (including West Lakes Shore). There were significant differences in frequencies of leaf shapes between populations within a State (p<0.0001). For example, Tasmanian collections from Burnie and Marion Bay differed markedly, with the latter being dominated by unlobed or slightly lobed leaves (Fig. 9). Applecross (WA, beside the Swan River) plants were mostly pinnatisect and bipinnatisect, whereas populations at Woodman’s Point and Golden Bay (on the open coast, 8 km and 40 km south of the river mouth respectively) had high proportions of crenate and entire leaves. It is interesting to compare this with the Western Australian herbarium data, mostly from ocean beaches, which were dominated by binnatisect and bipinnatisect leaves: either Woodman’s Point and Golden Bay are atypical of populations in the State, or in recent years there has been an increase of unlobed leaf forms within the State. Lakes Entrance, Victoria, which has a similar leaf variation distribution to NSW in our experience, also differed in distribution from the population from Queensland.

The first three coordinates of the PCA explained 70% of the variation in fruit traits from the eight sampled sites. The first coordinate showed a strong tendency for Western Australian fruits to differ in shape from the other States (Fig. 10). Eigenvectors showed that the main traits influencing this east-west separation were related to standardised fruit length (Western Australian distal fruit segments tended not to be as long), distance of the horns from the base (Western Australian fruits tended to have short horns located further towards the distal end of the proximal fruit segment) and hastate shape of the proximal segment (eastern fruits tended to have a longer, more acute apex to this segment and more protruding lateral horns). Fruits from the Atlantic coast of Spain showed similar trait variation to Western Australia, whereas Mediterranean fruits were aligned with the eastern Australian samples.

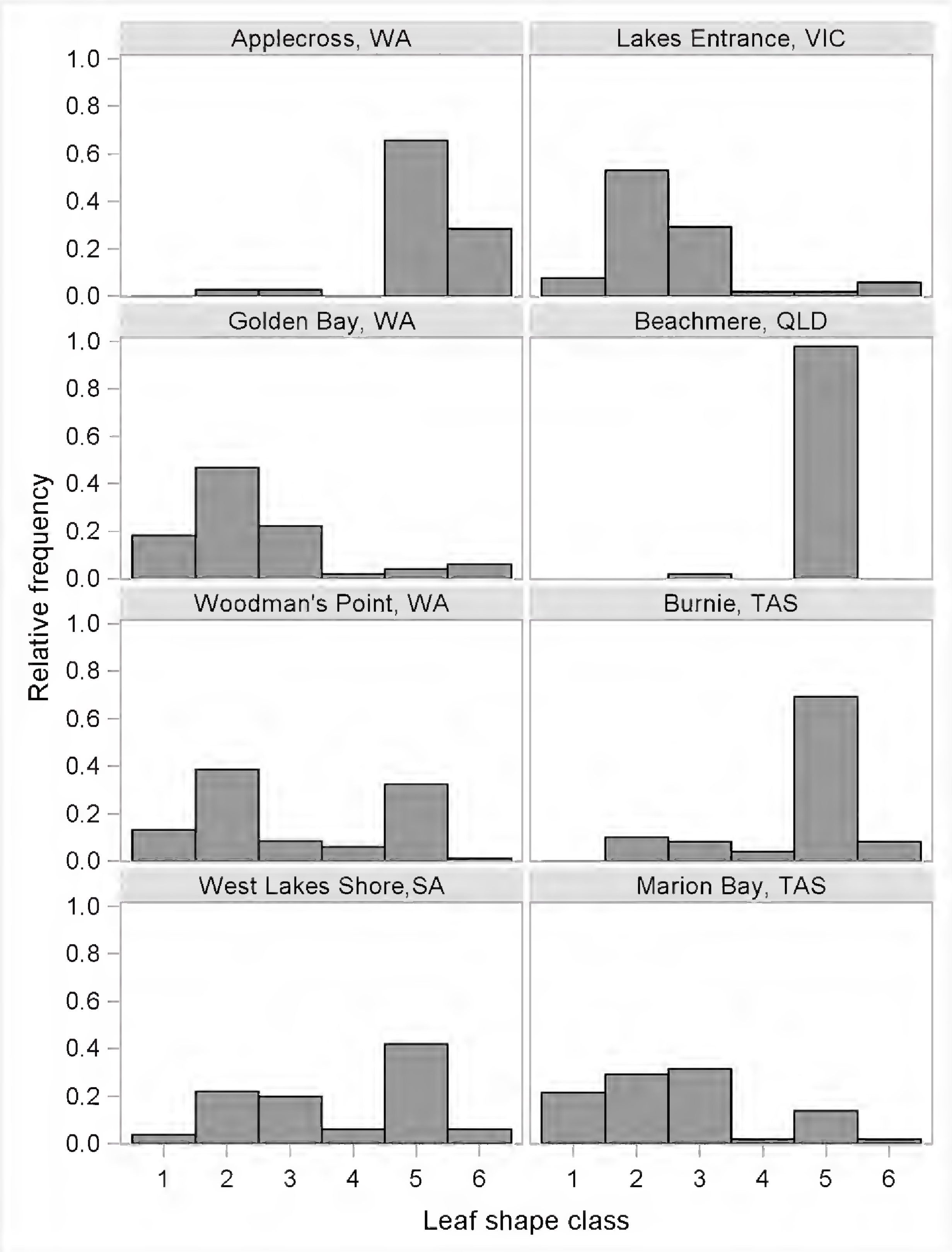

Fig. 9. Relative frequencies of leaf shape categories within populations of *Cakile maritima* from eight locations around Australia.

Discussion

Much of the broad chronology of the *Cakile* invasions of Australia, set out in previous publications by Rodman (1986) and Heyligers (2007) based only on locations and dates of collections, is supported by our research. However, by considering morphological traits we suggest modifications of important aspects of the invasion history and question others. Our results also need to be considered in the light of another publication on the species in Australia that appeared after Rodman's study (Cody & Cody 2004), in which a strong role for hybridisation/introgression was proposed. Our observations also have implications for the ways in which herbarium databases are being used by ecologists.

Invasion history

Previous interpretations of (largely) the same herbarium data have been based on the assumptions that (i) there has been a single introduction of each species, (ii) the invasion has been as a steadily moving wave (Sauer 1988), and (iii) the sequence of dates of the first herbarium collections in different regions reasonably reflects the invasion dynamics. There are reasons to doubt the accuracy of all these assumptions and hence the certainty of the conclusions.

(i) Our morphological evidence suggests strongly that there have been two or more introductions of *Cakile maritima* into Australia. The species did not simply sweep across the country from Western Australia, even though (a) that was the first place that it was recorded, (b) subsequent new collections followed a west to east sequence and (c) currents can carry floating objects rapidly from Western Australia into the Bight (Heyligers 2007). Species often arrive in a new country on several occasions, as both morphological and molecular studies have shown (e.g. Okada et al. 2009). Multiple invasion opportunities are provided inadvertently and deliberately by commerce. If these introductions differ morphologically and they subsequently inter-breed in the new range, we would then expect a greater range of variation than in a single ecotype within the native range: hybridisation between species is thus not required as an explanation for high levels of variation (see below). It has been suggested that *Cakile* spp. were originally dispersed into Australia in the ballast of ships (Rodman 1986). Vessels such as those collecting grain docked at many smaller ports in southern Australia, not just the capital cities, providing numerous opportunities for new introductions.

The range of morphologies present in *Cakile maritima* in Australia is suggestive of at least two recognised ecotypes from its native range. This is supported by Rodman's (1976) studies of glucosinolate variation. A collection of his from Victoria contained glucosinolates similar to those from the western Mediterranean (i.e. *Cakile maritima* subsp. *maritima,* in which horns on fruits are pronounced), whereas a sample from South Australia shared affinities with both western Europe (i.e. *Cakile maritima* subsp. *integrifolia,* in which horns are often barely distinguishable) and the Mediterranean. Based on morphology, Rodman also suggested that some material was *Cakile maritima* subsp. *baltica* (his determinations, written on specimens in various herbaria); in particular, he suggested that Western Australian material might be this subspecies (letter to H.J. Hewson, 1976, copy in the Western Australian Herbarium). Our morphometric analyses show clearly that Western Australian populations of *Cakile maritima* differ from eastern Australian samples in fruit shape. This difference

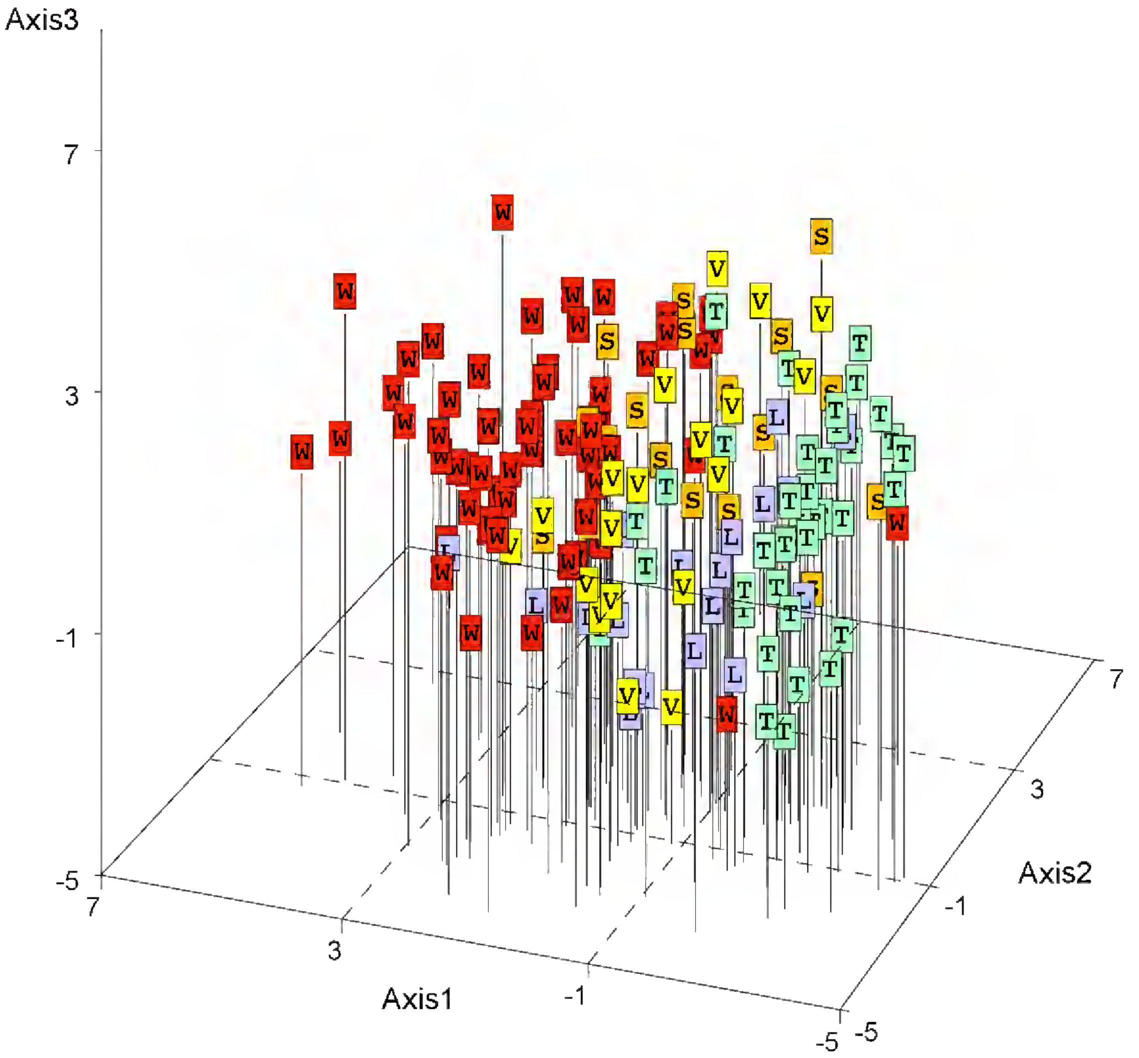

Fig. 10. PCA based on fruit traits of *Cakile maritima*. Letters refer to the region from which 19 plants were sampled from each of eight populations: Western Australia (W), South Australia (S), Victoria (V), Tasmania (T) and Lord Howe Island (L).

between west and east is supported by molecular studies currently underway using microsatellites (Ohadi *et al.* 2012). We did not have access to material of *Cakile maritima* subsp. *baltica*, however, to test Rodman's subspecies determination. We included scores from Ball's (1964) fruit line drawings of three subspecies (including *baltica*) in our PCA, but they did not encompass the variation seen within Australia (all subspecies were towards the same corner of the PCA scatter, perhaps because the Ball's drawings are somewhat simplified). We note, however, striking similarities between fruits collected from northern Spain (i.e. *Cakile maritima* subsp. *integrifolia*) and fruits from Western Australia (Fig.1g vs 1f).

We could not determine whether there have been multiple introductions of *Cakile edentula*. Only a single subspecies appears to be present in Australia and there is little variation in both fruit and leaf morphology. No chemical analyses have been done on Australian material, though we are currently doing microsatellite comparisons of Tasmanian and NSW/ Queensland populations.

(ii) Most species do not spread as neat "waves" of plants moving steadily across the landscape. The furthest-dispersing seeds may have a low probability of survival and establishment (especially outbreeding species and where potential dispersal distances are long) and by chance only some beaches are colonised at first. Species thus make long distance jumps, initiating new satellite populations well away from the region already invaded ("invasion by extremes" – Clark *et al.* 2001). The gaps later fill in as the species spreads more locally (see Cousens et al. 2009). This pattern was seen in northern New South Wales, where the northern edge of the *Cakile maritima* invasion was very diffuse, with some beaches within the zone of overlap still having only *Cakile edentula*.

(iii) Intensity of collecting has been very uneven in space and time, particularly in the 19th century, and has increased through time. Botanists often do not collect weeds and widespread invasive species (and these may not be a priority for herbaria). It would not be surprising if the first introductions to a region were overlooked for some considerable time, or if the first recorded location was a long way from the actual point of arrival. When *Cakile edentula* was first introduced there were few people collecting plants; travel was difficult and those collectors did not visit regions often. Then, as now, they did not necessarily make collections even if they saw them. For example, the first Australian collection of *Cakile edentula* (from Victoria) bears a comment that it had been noted from the region for about 20 years. The first Tasmanian collection of the species was by Mueller, who only appears to have visited beaches there on one of his three visits to the State (though others collected for him in Tasmania – R.W. Home pers. comm.). It is by no means certain that *Cakile edentula* was ever very abundant in Victoria and South Australia. We suggest, therefore, that the location of the first arrival of *Cakile edentula* in the south-east is very uncertain, even to the level of the State.

Another area in which the chronology is uncertain is The Great Australian Bight. This remote area is seldom collected thoroughly. The dates of first appearance of the two species and the disappearance of *Cakile edentula* (indeed, it may still occur there), based on herbarium collections, are likely to be very unreliable. However, it seems likely that it persisted longer there than elsewhere in South Australia and much of Victoria. A similar ongoing low collection frequency in Queensland, especially on the small islands of the Barrier Reef, make *Cakile edentula* arrival dates, as well as its current distribution, also uncertain.

Rate of spread & species replacement

Despite the uncertainties due to low sampling effort and the possibility of multiple introductions, it has been tempting to estimate the rate at which the species have spread. Estimates from the Pacific Coast of North America based on herbarium collections are 64 km yr^{-1} for *Cakile edentula* and 53 km yr^{-1} for *Cakile maritima* (Barbour & Rodman 1970). For Australia, Rodman (1986) estimated rates for the two species of 48 km yr^{-1} and 95 km yr^{-1} respectively, commenting on the high latter value. However, if we discount the spread of *Cakile maritima* from Western Australia to South Australia, a figure of less than half is obtained (around 40 km yr^{-1}), more in line with other estimates. Comparison of our NSW/Queensland survey in 2012 with Heyligers' in 1998/9, taking the most northern NSW location in each case and ignoring the new incursion in Queensland (which may be of different origin), and assuming that each survey accurately identified the range limit, leads to a rate of spread of about 14 km yr^{-1}. This lower rate of spread is perhaps not surprising, as it is against the direction of the strong East Australian Current which Heyligers (2007) postulated as an impediment to coastal invasions moving northwards (though near-shore currents in this region are often northwards). Currents vary in direction and strength around the coast of Australia and with season. It is clear, however, that rates of invasion by *Cakile* are much slower than would be predicted from the rates of seed dispersal predicted from bottles and cards released offshore (Heyligers 2007). Flotation and viability of most seeds following submersion is very limited (Heyligers 2007). Nearshore movement is likely to be much more restricted than offshore, though seeds (and entire beaches) can be washed into the sea by storms.

Rodman's (1986) estimate of 40 years for the rate of replacement of *Cakile edentula* by *Cakile maritima* was based on a time series of the relative frequency of new collections of each species in the whole of South Australia and Victoria. The total number of specimens was very low, especially for *Cakile edentula* in the early years. Once again, the low sampling effort and reliance on chance collections results in extreme uncertainty in this estimate of 40 years. After *Cakile maritima* arrived at a site, its (perhaps) greater abundance would immediately make *Cakile edentula* harder to find, even if still present. However, even given these uncertainties, this rate of replacement at a geographic scale, on beaches where there often appears to be much empty space between mature plants, seems remarkably rapid. Within some locations, replacement would presumably have been even faster. Heyligers (1984) states that the replacement occurred over one or two decades along sections of coast. At the time of his paper both species could still be found together on beaches in southern NSW, whereas that is no longer the case less than thirty years later. Another example is Lord Howe Island, where the complete replacement occurred sometime after 1978 (even though all samples from that date and earlier were *Cakile edentula*, in the absence of proper surveys we cannot be certain that *Cakile maritima* had not already arrived).

Researchers in North America have investigated several possible factors causing the species replacement. Boyd & Barbour (1993) found that *Cakile maritima* was a better competitor than *Cakile edentula* in a growth chamber but not in the field but dismissed direct competition as a mechanism of replacement because adult plants on a beach are typically widely spaced. They overlooked the fact that densities of seedlings can be extremely high at a fine scale (Keddy 1982; Donohue 1997) due to highly restricted dispersal of proximal fruit segments, though by maturity only a single plant often remains in these clumps. Cody & Cody (2004) found a correlation between plant performance and distance between mature neighbours on a South Australian beach, suggesting that adult plants are competing. Instead of direct competition as the replacement mechanism, Boyd & Barbour (1993) speculated that the estimated (up to) 18-fold greater lifetime fecundity in a Californian foredune meant that *Cakile maritima* would be more successful in colonising limited sites of suitable habitat through lottery competition (Chesson & Warner 1981). *Cakile maritima* (or the genotypes of that species introduced into California) may be inherently more fecund than *Cakile edentula*, or as an outbreeder it may have been able to evolve more effectively to its new environment. Looking at a beach colonised by *Cakile*, one is struck by the large areas of apparently suitable habitat that are unoccupied. Given that entire sections of beach can be washed away in storms, greater fecundity would also make it more likely that *Cakile maritima* would be the species to recolonise from elsewhere along the coast after disturbance. Indeed, we suspect that many beaches, while supporting low densities of *Cakile* plants, may be sink populations while areas in which plants reach high densities (and undergo strong competition) may be source populations (Pulliam 1988: analysis of data from Boyd & Barbour's study site (Boyd 1991) resulted in a net reproductive rate less than 1, indicating that it was a sink population). The large variations in morphology between beaches that we report within a State may reflect chance recolonisations by a narrow range of morphotypes following complete population removal. Thus, the success of *Cakile maritima* may be enhanced by disturbance interacting with fecundity in a spatial context.

Alternatively, it is plausible that the disappearance of *Cakile edentula* could have been driven by an independent variable: the arrival of *Cakile maritima* was just coincidental. Indeed, Heyligers (2007) is of the opinion that *Cakile edentula* was declining in South Australia and western Victoria prior to the arrival of *Cakile maritima*. Given that *Cakile edentula* had successfully invaded Australian temperate, Mediterranean and sub-tropical climates, it is unlikely that climate change alone would have caused the demise of *Cakile edentula* over a large geographic range. If *Cakile edentula* spread from a single introduction, then this indicates either considerable phenotypic plasticity in relation to climate or a great ability to adapt (despite being an inbreeder). An alternative explanation is that a disease arrived after *Cakile edentula* (perhaps on *Cakile maritima*) and this was sufficient to make its net reproductive rate less than one. Both species are hosts to the fungal pathogen *Alternaria brassicicola* (Thrall *et al.* 2000): late in the season it is common in southern states to see populations of *Cakile maritima* in which every plant is blackened by the disease and they quickly die. The "Red Queen" hypothesis would predict that an inbreeder would be less able to adapt in response to evolution in the pathogenicity of the disease than an outbreeder (Antonovics *et al.* 2007). However, we have found *Alternaria brassicicola* to be present on herbarium specimens of *Cakile edentula* from before the arrival of the second host (although it is possible that more virulent pathotypes have arrived or evolved since). Bock (2008) found no difference between the plant species in susceptibility to five *Cakile maritima*-derived isolates of *Alternaria brassicicola*.

Perhaps the loss of *Cakile edentula* could have been caused indirectly by *Cakile maritima*, via another factor. For example, the arrival of *Cakile maritima* may have increased overall *Cakile* plant density, which in turn could have affected disease epidemiology. A larger population of diseased *Cakile maritima* plants, producing a greater pathogen load on *Cakile edentula*, could then have reduced the reproductive output of the latter, causing its net reproductive rate to be less than 1. The rapid coevolution of the pathogen with *Cakile maritima* (Linde *et al.* 2010) may also have generated pathotypes that were particularly damaging to *Cakile edentula* (though see Bock 2008). Predation/herbivory may be another interactive factor. Seeds of both species can be heavily predated; however, Boyd (1988) excluded differential herbivory as the primary cause of the replacement in California.

The role of hybridisation

Putative hybrids are occasionally found in the field, supported by herbarium specimens, and hybrids can be produced in the glasshouse (Rodman 1974; C. Willis pers. comm. and our own unpublished work). In our experience these hybrids are most common on those Tasmanian beaches where *Cakile maritima* has only recently arrived and where *Cakile edentula* still dominates. Although we have observed a greater preference of pollinators for *Cakile maritima* in mixed populations (unpublished data), perhaps at low *Cakile maritima* relative frequency insects may move from one plant species to another more often than when *Cakile maritima* dominates populations. In many instances, however, we believe that the wide range of morphological variation in *Cakile maritima* (perhaps due to multiple introductions), together with a lack of familiarity with the now localised *Cakile edentula*, has misled some observers into concluding that hybrids are more common than is in fact the case. Eichler (1965), for example, stated that intermediates were common in South Australia, constituting a hybrid swarm, but his herbarium specimens are all within the range of variation expected for *Cakile maritima* in Europe. One web site (*Weeds of Australia: Queensland Biosecurity Edition* – Queensland Government, 2012) states that "intermediates between the two plants are common or dominant in some areas" but the basis of this statement is unclear (their photographs of *Cakile edentula* are clearly *Cakile maritima*). Several books (though not the major State or national floras) and web sites from Australia show pictures of "*Cakile edentula*" that fall clearly within the variation within *Cakile maritima* and outside the range of variation within *Cakile edentula* (e.g. Richardson et al. 2006; Harris *et al.* 2001; Queensland Government 2012). Perhaps these authors mistakenly assume that non-pinnatisect leaved plants must be either *Cakile edentula* or hybrids?

Cody & Cody (2004) concluded from their survey of one South Australian population and one in British Columbia that in Australia hybridisation has played a major role in the demise of *Cakile edentula*. They suggest that the two species have produced an "introgressive swarm" in Australia, whereby the genes of *Cakile edentula* have mixed with *Cakile maritima* rather than one species simply replacing the other. The mechanism for the introgression resulting in a stable polymorphism was not proposed. Repeated back-crossing of selectively neutral hybrids to one of the parents (*Cakile maritima*) would probably have led to the rapid disappearance of traits from the other species rather than a stable polymorphism. A selective advantage in the hybrids, resulting in transgressive segregation, would require competition or another mechanism to account for the loss of the two parental species; hybrid species are often associated with new, rather than the parental, habitats (Rieseberg et al. 1999). In any case, if introgression has occurred in Australia, why has it not occurred in North America where the two species are also sympatric?

In addition to instances of putative hybrids with intermediate characters in the field and produced artificially, Cody & Cody's argument is based on three observations: (i) morphological variation in *Cakile maritima* at Westlake Shores (sic), South Australia is much greater than in North America (no reference was made to variation in Europe); (ii) floral, fruit and leaf morphological characters at that site cover the range of variation documented for the two species; (iii) and leaf morphology at Westlake Shores is bimodal, "suggestive of genetic variability produced by introgression". It should be noted that the morphological descriptions and dimensions that they quote are only from Floras describing the species in their introduced range (Australia and North America): introductions in different countries may represent different regional morphotypes from the native range. Indeed, fruit shape variation in *Cakile maritima* is far greater in its native range than in North America (e.g. Ball 1964) and a different conclusion may have been reached if they had based their comparisons of Australian material on Flora Europaea (Tutin *et al.* 1993). Cody & Cody's petal length measurements, which they compare to the ranges given in floras, were based only on the length of the flat, open part of the petal (the limb) rather than the entire petal used in those floras. Allowing for this difference in metrics, petal length data for Australian *Cakile maritima* also fall within the ranges reported for *Cakile maritima* in Europe [note that Flora Europaea gives petal lengths for *Cakile maritima* of 5–14 mm, whereas Cody & Cody follow Australian floras in stating that petal length >8 mm is diagnostic for the species; Rodman (1974) gives ranges of 8–14 mm for *Cakile maritima* and 4.6–9.7 mm for *Cakile edentula*]. In fact, the ranges of petal limb lengths for *Cakile maritima* in their Australian and Canadian sites were broadly similar. Petal widths, as Cody & Cody show, are better diagnostic characters for the two species; however, they were not measured at their South Australian site.

The extreme leaf shapes that Cody & Cody observed in Australia – entire and pinnatisect – can co-occur on beaches within *Cakile maritima*'s home range as well as in different regions (Ciccarelli *et al.* 2010; Gandour *et al.* 2008; Mouterde 1970, Ross-Craig 1958; Tutin *et al.* 1993; Davy *et al.* 2006). Material from western North America, on which Cody & Cody base their conclusions, appears to fit within a narrow part of the species variation (pinnatisect leaves with distinctly horned fruits), most likely from the Mediterranean (i.e. *S. m. maritima*). It is also worth noting that considerable variation in leaf and fruit morphology, including bimodality in leaf shape (Fig. 8), is found in Western Australia, where *Cakile maritima* first established and where *Cakile edentula* has never been confirmed west of Esperance. Bimodality may arise for reasons other than introgression: two genetically determined *Cakile maritima* leaf biotypes subject to environmental variation and scored on a linear scale, for example, would result in two modes. The scale may also include shapes that, though visually intermediate, are naturally uncommon.

In summary, although we cannot rule out introgression in Australia, the evidence in its favour is very weak. Variation resulting from intermixing of multiple introductions of different morphotypes of the same species, overlooked by Cody & Cody as a possibility, or introduction from a single morphologically variable population, could just as easily explain their results and ours. It would also not require us to find a plausible reason why introgression has occurred on one continent and not the other, despite the fact that pollinators in British Columbia move readily between the two species. Clearly, however, molecular research is required to decide definitively between the alternatives.

Issues with herbarium and survey data

The data provided by herbaria are a wonderful resource, allowing us to investigate the history of the collection of species and biogeography. However, considerable caution is needed. Herbarium samples do not usually represent a structured survey; collection intensity varies considerably over time and between regions resulting in large gaps in time series. Herbarium records are also inevitably an over-estimate of the time of first appearance (they cannot be an under-estimate). Errors in the order of tens of decades and tens if not hundreds of kilometres are therefore possible in Australia. Herbarium data are increasingly being made available via electronic means, and may be combined with data unsupported by voucher specimens. The Atlas of Living Australia (ALA), Australia's Virtual Herbarium (AVH) and The Global Biodiversity Information Facility (GBIF), for example, have made it tantalisingly easy to access distribution data for ecological analysis (e.g. Gallagher *et al.* 2010; Aikio *et al.* 2010). It must be appreciated, however, that these databases do not constitute primary data. When checking herbarium sheets against databases, it is not uncommon to find errors in geographic coordinates as well as mis-identification of species, especially in difficult taxa. Such errors can be critical when trying to deduce invasion history and bioclimatic adaptation. We are concerned that many such studies do not "ground truth" their database-derived information. In the case of *Cakile*, it is common to find specimens attributed to the wrong species (see also Cousens & Cousens 2011) and even after corrections have been made in herbaria it can take some time before these data flow through to databases such as ALA and AVH. Data from unvouchered sources (e.g. Natural Values Atlas, Tasmanian Government) may also contain potentially erroneous information which cannot be verified through examination of specimens. Given the acknowledged potential for misidentification of *Cakile* plants in Australia, we have chosen to exclude data from unvouchered sources for this study. We note that it was only by going back to the actual specimens were we able to deduce that *Cakile maritima* probably did not spread from Western Australia to the east (supported by recent molecular study – Ohadi *et al.* 2012): latitude, longitude and collection date were insufficient to determine the invasion history correctly.

Similarly, errors occur in survey data. In our surveys time constraints and accessibility meant that not all beaches were visited, so outlying populations may have been missed. Many beaches contained no plants of either species, or a low number of a single species, which may be because of severe recent disturbance episodes and failure to establish in the current season rather than due to a true absence of the species from that location. It is also plausible that if *Cakile edentula* was always scarce in a region, then the arrival of a dense *Cakile maritima* population would make it more difficult to find, even if its abundance did not change or it is still present at a low level. However, at a given beach the usually very narrow band occupied by the species was searched thoroughly for a distance of up to 500 m if one of the species had not been found; most plants were well past the seedling stage. Once the characteristic differences between the species are appreciated (colour, growth form, flower size), it is possible to distinguish them from a distance of over 5–10 m. We are also able to compare Heyligers' (unpublished) surveys in the late 1990s with our own and the results appear to be reasonably consistent.

Given the various sources of error, estimates of the time from first arrival of *Cakile maritima* to complete replacement of *Cakile edentula* within a region are particularly speculative. Herbarium collections rarely contain information on whether the other species of *Cakile* was present and in any case without material of both species from a site we cannot necessarily rely on collector identifications (given the common misidentification of the species). Semi-quantitative field surveys have now been conducted on two occasions by researchers fully aware of the species diagnostics and repetition of these surveys in future years will provide better estimates of rates of replacement, although the southern expansion of *Cakile maritima* appears to be rapidly reaching its conclusion. In Tasmania, monocultures of *Cakile edentula* can only be found in a small area in the southeast; annual monitoring of these beaches would be able to give a clear picture of the invasion dynamics as *Cakile maritima* arrives. Similarly, beaches in a 150 km stretch of coastline in eastern Tasmania could be selected to chart the hypothesised loss of *Cakile edentula*. In NSW there is a 270 km gap in the distribution of *Cakile maritima* occupied by *Cakile edentula* which would also be worth monitoring, along with the area north of Moreton Bay. If it is confirmed that the Queensland populations are a separate introduction – which we hypothesise on the base of morphological variation – then there is an opportunity to examine the population genetics that occurs in future as these come into contact with those moving northwards in NSW.

Postscript on taxonomy

Having tried to use *Flora Europaea* and Ball's (1964) drawings to distinguish *Cakile maritima* subspecies, we became increasingly unconvinced by their diagnostic keys. Observations by one of us (RC) in northern and southern Spain, and a survey of photographs on the internet and botanical drawings in regional European floras and plant picture books, suggest that keys may not adequately represent the geographic variation. We suggest that a review is needed, preferably sampling within and between populations (as in our study) rather than relying on herbaria, to determine how morphological variation correlates with regional molecular data. Moreover, there remains some confusion in the naming of the subspecies, particularly with regard to *maritima*, *integrifolia* and *aegyptiaca*. This requires the attention of a taxonomist with access to possible lectotypes.

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Replacement of *Cakile edentula* with *Cakile maritima* in New South Wales and on Lord Howe Island

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***Abstract*:** Two species of *Cakile* (Brassicaceae) have been introduced to Australia and the genus has been a common feature on the beaches of NSW for over 130 years; *Cakile edentula* has been present for at least 148 years (in NSW since about 1870), while *Cakile maritima* arrived approximately 114 years ago, (in NSW since about 1969). Collections at CANB and NSW confirm that since around 1970 plants more like *Cakile maritima* have almost entirely replaced *Cakile edentula* along the NSW coast. A similar phenomenon is reported for Lord Howe Island.

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Introduction

The genus *Cakile* (family Brassicaceae) contains seven species, all of which are naturally found only in the northern hemisphere. Two species have been introduced into Australia, *Cakile edentula* (American Sea Rocket) and *Cakile maritima* (European Sea Rocket). *Cakile edentula* var. *edentula* is the taxon found in Australia and is indigenous to the east coast of North America, where it grows on coastal shores, from northern Canada south to Florida. *Cakile maritima* subsp. *maritima*, the taxon found in Australia, is indigenous to Europe and northern Africa, and grows naturally throughout the Mediterranean and along the Atlantic coast. These herbaceous annuals are largely restricted to sandy beaches where they grow as sand-binding, strandline plants. The species grow in association with a suite of indigenous and several well-established introduced beach species. These species are termed ‘drift-line pioneers’ by Heyligers (1985) and in this regard *Cakile* is likened by that author to the natives *Atriplex cinerea* and *Austrofestuca littoralis*. *Cakile* is mostly found growing on coastal beaches, but sometimes occurs on the edges of saline coastal lakes with native saltmarsh species.

The spread of *Cakile edentula* and *Cakile maritima* along the NSW coast, and replacement of the former by the latter, has previously been documented (e.g. Heyligers 2007). A similar phenomenon on Lord Howe Island, a remote oceanic island 600 km east of NSW, has gone unreported until now. The mechanism behind this replacement has not been satisfactorily elucidated, although several hypotheses have been discussed in the past (e.g. Rodman 1986; Heyligers 2007). *Cousens* et al. (2013) reviewed the history of invasion of *Cakile* in Australia and found that *Cakile maritima* was introduced into Australia from morphologically distinct races. This explains the regional variation within Australia and the high variability in the appearance of this taxon in the southeast, without the need for introgression of *Cakile edentula* into *Cakile maritima*.

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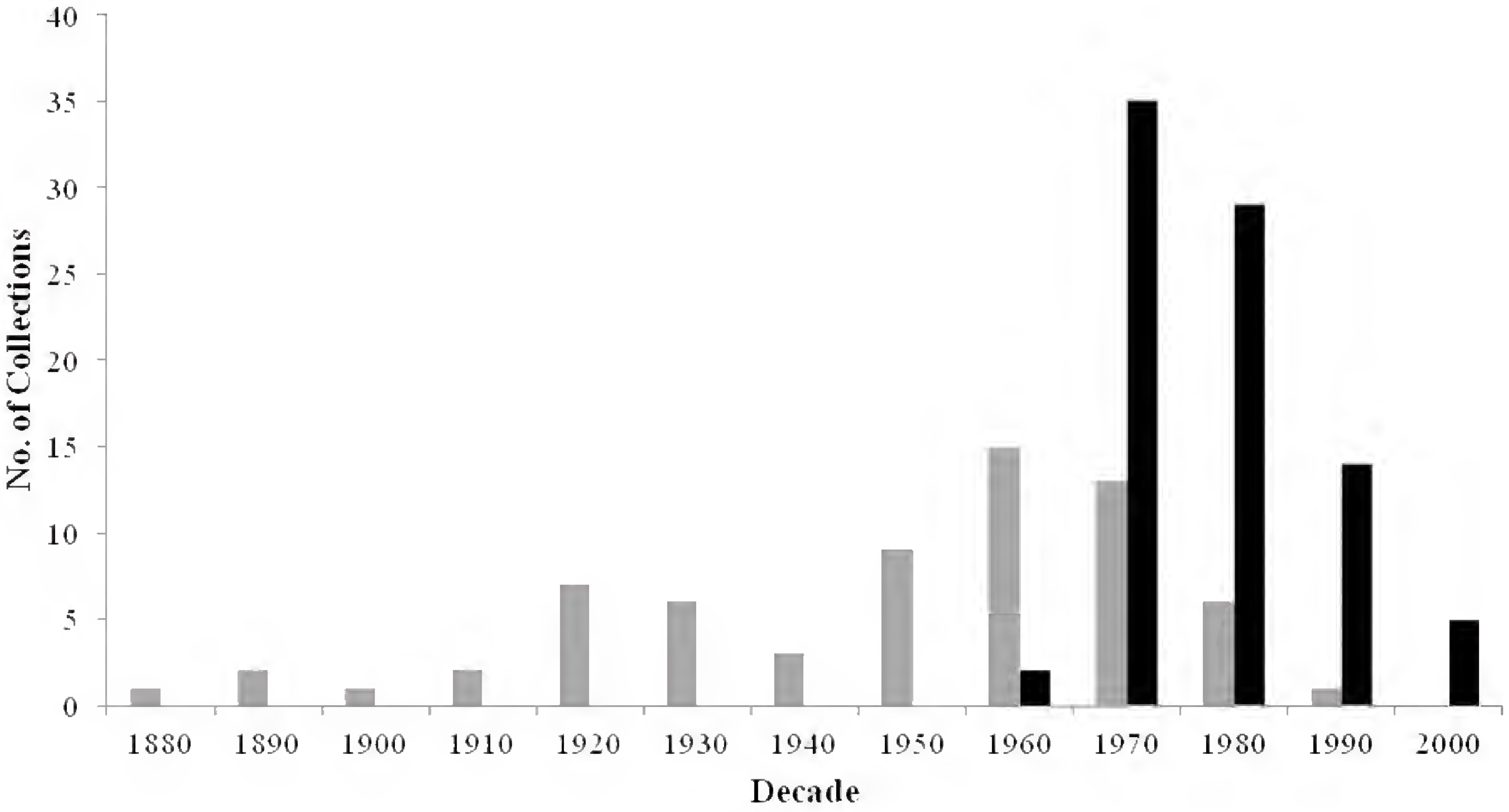

Fig. 1. Number of collections of *Cakile* from NSW at CANB and NSW, combined for each taxon in each decade. Grey – *Cakile edentula*; black – *Cakile maritima*.

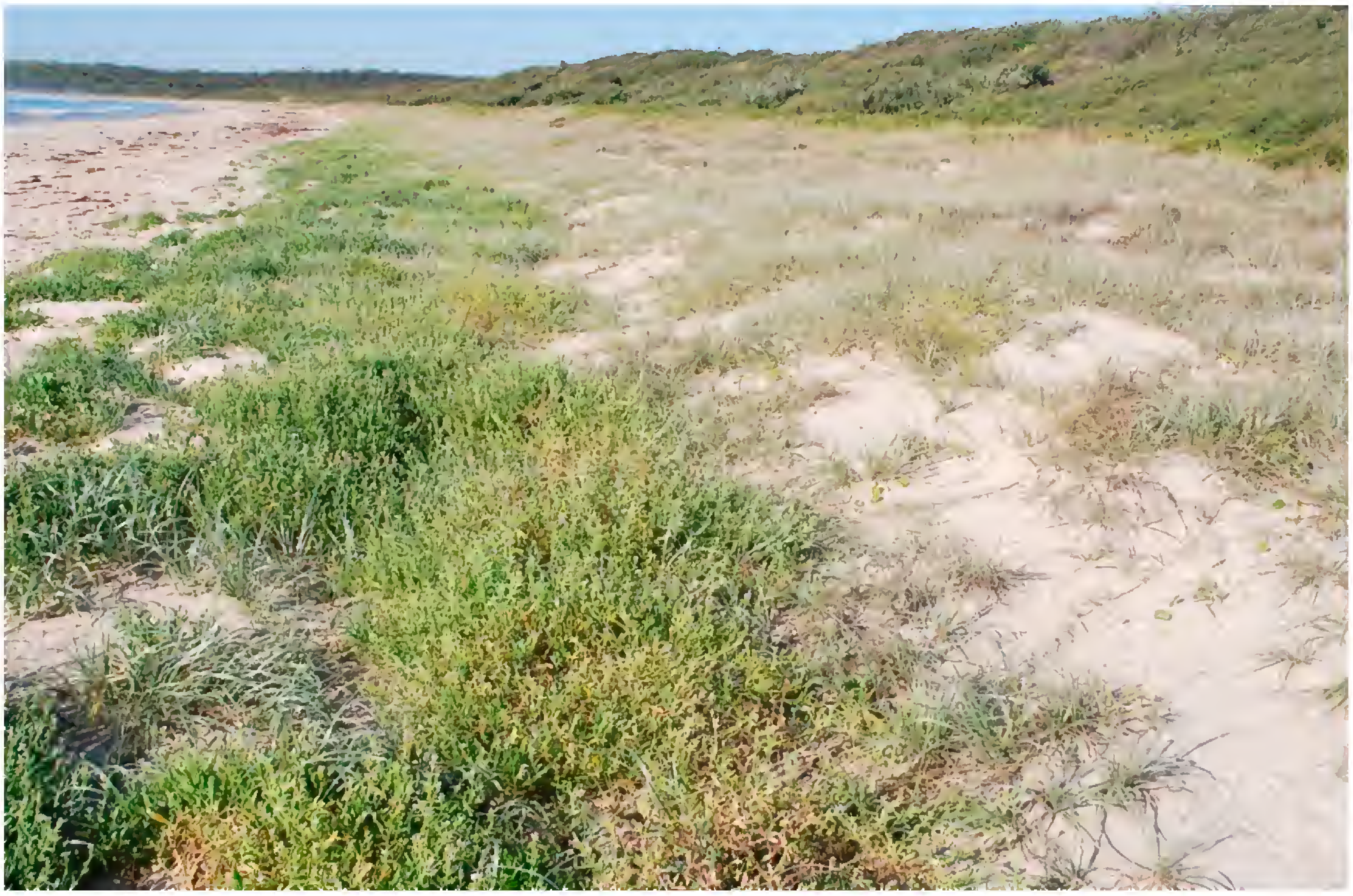

Fig. 2. A dense stand of *Cakile maritima*, to left, growing along the strandline on Berrara Beach, south coast of NSW. Date: 02 January 2012.

Cakile in the southwest Pacific

Cakile edentula was first recorded in Australia at Phillip Island in Victoria in 1863, while *Cakile maritima* was first collected at Fremantle, Western Australia in 1897 (Heyligers 1985). The taxa are thought to have been brought to Australia in the ballast water of ships visiting from the northern hemisphere. The first collections and locations in NSW were respectively, Manly in 1870 (*Cakile edentula*) and Woy Woy in 1969 (*Cakile maritima*) (Heyligers 1989). *Cakile edentula* has been present in NSW for at least 142 years and by the 1920s had colonised the whole coast. *Cakile maritima* has been present in NSW for about 43 years. There was thus a 99 year gap between the first recorded observations of the two species in NSW; this compares with a 34 year gap between their earliest collections in Australia.

Extra-Australian occurrences of *Cakile* in the southwest Pacific are Lord Howe Island, the Kermadec Islands, New Zealand (North and South Islands) and Norfolk Island, the latter island with one record only, in 1902 (Maiden 1904), though Green (1994) noted that Maiden's 1902 specimen from Norfolk Island was actually *Cakile edentula* rather than *Cakile maritima* as suggested by Maiden. There have been no other records of *Cakile* from that island. At least some of these occurrences are likely to have been self introductions from Australia, rather than human assisted dispersals.

Methods

Lists of collections of both *Cakile* species in NSW and on Lord Howe Island were obtained from the National Herbarium of New South Wales in Sydney (NSW) and the Australian National Herbarium in Canberra (CANB). Those collections gathered from locations in NSW were identified and analysed according to their date of collection. Observations of *Cakile* on Lord Howe Island were made on a visit to that island in late 2009.

Table 1. Specimen collection dates of *Cakile* from Lord Howe Island (data from NSW and CANB herbaria)

Cakile edentula	***Cakile maritima***
Oct. 1898	-
Sept. 1908	-
August 1911	-
May 1920	-
27 Oct. 1963	-
16 July 1965	-
23 Sept. 1970	-
1 Sept. 1971	-
15 July 1978	-
23 Mar. 1979	-
-	17 July 2000
-	12 Nov. 2000
-	Nov. 2009 (observed, K.Mills)
-	Feb. 2010

Results

Cakile on the NSW Coast

Records of *Cakile* specimens along the NSW coast (lodged at NSW and CANB) were combined, based on species and decade of collection and demonstrate the demise of *Cakile edentula* and the expansion of *Cakile maritima* along the NSW coast (Figure 1). In the 1970s, *Cakile edentula* apparently began to disappear and plants identified as *Cakile maritima* began to be regularly collected. By about 2000 plants resembling *Cakile edentula* had all but disappeared from the collections and been replaced by plants more like *Cakile maritima*. This change has been documented in various papers by Heyligers (e.g. 1998).

Cakile on Lord Howe Island

On Lord Howe Island, 600 km east of the coast of NSW, both *Cakile* species have been recorded. The first record of the genus on the island was *Cakile edentula* in 1898 (NSW collection by E. King, October 1898) (Table 1), 28 years after it was first collected in NSW (Heyligers 1989). Rodd and Pickard (1983) list *Cakile edentula* as a "naturalized non-native species" for the island, although Pickard (1983) does not list is as a characteristic or common plant species in the beach communities that he describes.

Cakile edentula has also been replaced by *Cakile maritima* on Lord Howe Island, as evident from an analysis of herbarium collections and recent field observations (Table 1). Collections held at NSW indicate that *Cakile edentula* was collected on the island up to 1979; unfortunately, there are no specimens in either herbarium for 21 years after that year, though Green (1994) documented it for the island at that time. The first collections of *Cakile maritima* from Lord Howe Island are from 2000. Recent observations of *Cakile* on Lord Howe Island by the author are only of *Cakile maritima* (Mills 2009). As has occurred on the coast of New South Wales, *Cakile edentula* has disappeared on Lord Howe Island and been replaced by *Cakile maritima*.

Conclusion

The occurrence, abundance and distribution of introduced plants (exotics, weeds) is often highly dynamic, reflecting the unstable environments in which most weeds proliferate. Many of the species that are weeds in Australia are colonisers of disturbed ground in their region of origin, making them particularly successful introductions. In the case of *Cakile* in Australia, the species inhabit a naturally dynamic upper beach environment, as they do in their native countries.

Two species of *Cakile* have been present in Australia for well over 100 years. *Cakile edentula* had colonised the entire NSW coast by about 1920, while *Cakile maritima* was recorded along the whole coast by at least the 1970s. The "replacement" of the former by the latter taxon in southern Australia was noted by other workers (Rodman 1986; Cody & Cody 2004; Heyligers 1998), the results obtained from field observations and herbaria records. The replacement of *Cakile edentula* by *Cakile maritima* along the NSW coast and on Lord Howe Island is consistent with observations on other coasts in southern Australia. Rodman (1986) noted a similar replacement of *Cakile edentula* with *Cakile maritima* on the Pacific coast of North America; interestingly, both species are introduced to that coast.

Acknowledgements

Data used in this work has come from the Australian National Herbarium Specimen Information Register (ANHSIR) database [extract at CANB, Excel file 2010] Australian National Herbarium (CANB) Canberra, and the database of specimens at the National Herbarium of New South Wales (NSW), Royal Botanic Gardens and Domain Trust Sydney. Doug Benson made useful comments on a draft of the paper.

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Survival of *Casuarina cunninghamiana* on a recovering sand-bed stream in the Wollombi Valley of coastal New South Wales

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***Abstract*:** The successful management and restoration of riparian corridors in Australia is currently hindered by our poor understanding of the links between hydrology, fluvial geomorphology and plant population dynamics. The aim of the current study was to determine the survival rates of *Casuarina cunninghamiana* subsp. *cunninghamiana* Miq. (family Casuarinaceae) on a sand-bed stream in the Wollombi Valley, a tributary of the Hunter River system, in coastal New South Wales (lat 33°02'S; long 151°10'E). A population planted on the banks of Dairy Arm in 1987, as part of river training works, was used to determine the long-term (24-year) survival rate. A bankfull flood in June 2011 provided an opportunity to examine the survival response of seedlings regenerating naturally within the channel. We found that 24% of the seedlings planted on the banks in 1987 had survived to adulthood. The bankfull flood significantly decreased (d.f. = 14; W= - 30; p = 0.0024) median seedling density within the channel from 12 to 2 individuals per 100 m^2. Seedling survival varied with height, with seedlings > 15 cm more likely to survive the bankfull flood. The percentage of seedlings partially buried by sediment was significantly higher (d.f. = 14; W = 13; p = 0.016) after flood compared to before flood. Seedling density was positively correlated with the amount of bare ground prior to the flood (r = 0.61; p = 0.02), but this relationship was no longer significant after flood (r = 0.18; p = 0.53). 37% of the seedlings surveyed showed evidence of grazing. Our results confirm that hydrogeomorphic processes associated with a bankfull flood affect the survival of *Casuarina cunninghamiana* seedlings. The management implications of our findings are discussed in terms of riparian revegetation techniques and the geomorphic recovery of over-widened sand-bed streams.

Key words: *River Sheoak, seedling survivorship, flood disturbance, river training works, riparian vegetation, fluvial geomorphology*

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Introduction

Casuarina cunninghamiana (River Sheoak) occurs naturally in New South Wales (NSW), the Australian Capital Territory (ACT), Queensland and the Northern Territory of Australia. Of the two subspecies known, only *Casuarina cunninghamiana* subsp. *cunninghamiana* occurs in NSW and the ACT (Wilson & Johnson 1990). The natural habitats of this tree species are riparian corridors along coastal and inland river systems where it plays an important geomorphic and ecological role by establishing in channels, locally reducing flow velocities and accelerating bench formation (Erskine *et al.* 2009). Bench formation is important to the geomorphic recovery of sand-bed streams as one of the processes through which

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channel contraction of over-widened streams occurs (Erskine *et al.* 2012). Many sand-bed streams have been over-widened by historical land management practices combined with the impacts of catastrophic floods or a series of large floods (Erskine & Chalmers 2009; Erskine *et al.* 2012). Self-sustaining populations of *Casuarina cunninghamiana* are essential for the stability and recovery of sand-bed streams especially those that have been extensively cleared. This species is ecologically important because it lowers stream temperature by shading, provides carbon (including large wood) to rivers and provides habitat for terrestrial, riparian and aquatic fauna (Roberts & Marston 2011). Where *Casuarina cunninghamiana* is the dominant tree species, its cover also influences understorey composition (Chalmers *et al.* 2012).

Flood-tolerant plant species are adapted to survive the physical forces of flood, as well as periods of waterlogging or inundation (Kozlowski 1984; Van Steenis 1987). The degree of physical damage, inundation and waterlogging depends on the size (intensity) and duration of flood events, as well as the relative height of the landforms on which plants are growing. Survival of many riparian species also depends on their ability to access alluvial aquifers; flood frequency is important here because floodwaters replenish both groundwater and soil water (Roberts *et al.* 2000; Overton *et al.* 2006; Chalmers *et al.* 2009). Geomorphological processes that are mediated by flood and interact with riparian vegetation include scouring of the bed, stream bank erosion, removal of low elevation landforms (e.g. bars and benches) and the deposition of sediment to form new landforms (Bendix & Hupp 2000; Gurnell *et al.* 2001; Erskine *et al.* 2009; Erskine *et al.* 2012; Gurnell *et al.* 2012). Non flood-mediated factors like livestock grazing also affect riparian plant survival (Robertson & Rowling 2000; Friedman & Lee 2002; Chalmers *et al.* 2006). Studies investigating the survival of *Casuarina cunninghamiana* are limited and the findings have sometimes been contradictory (Roberts & Marston 2011).

Catastrophic floods are likely to affect trees of any size class growing on both low and high elevation fluvial landforms, but they are relatively rare. Smaller floods and flows (e.g. bankfull discharge) will have less impact on large established trees and on higher elevation fluvial landforms (e.g. floodplains), but do occur relatively frequently. These frequent, smaller floods are a barrier to the restoration of riparian zones if they result in repeated loss of individual plants by scouring. Understanding the survival responses of riparian trees to frequent floods will allow us to design methods to improve restoration outcomes. For example, the historical practice of planting long cuttings of exotic Willows and Poplars to stabilise stream banks was to reduce plant loss during floods but introduced exotic species with little ecological value into the landscape. A much better solution to the problem of flood scour is Bill Hicks' long-stem planting technique, which enables native species to be planted deeply into stream banks (Hicks *et al.* 1999).

Between 1954 and 1993 extensive river training works to address channel instability by installing a range of structural works (brush, mesh or rock fences or rock training walls) and tree plantings were undertaken by the NSW Department of Land and Water Conservation (DLWC) on streams in the Hunter Valley (Erskine 1990; 1992; 2001). *Casuarina cunninghamiana* was planted as part of the river training works on a sand-bed stream (Dairy Arm) in the Wollombi Valley in 1987; subsequently naturally regenerating seedlings have been observed in the channel adjacent to this planting. These circumstances provided an opportunity to investigate the survival rates of *Casuarina cunninghamiana* on two different time-scales on a stream for which the hydrology and geomorphology are well understood. The aim of the current study was to measure: (1) the long-term survival of the cohort planted in 1987; and (2) the survival response of naturally regenerating individuals in the channel following a bankfull flood event in 2011.

Study Area

The study area covers pastoral land in the riparian corridor of Dairy Arm (lat 33°02'S; long 151°10'E), a tributary of upper Wollombi Brook in the Hunter Valley, NSW (Figure 1). Dairy Arm (total catchment area 40 km^2) is a small capacity sand-bed stream flanked by a low floodplain. The geology of the upper Wollombi Brook drainage basin is intercalated quartzose sandstone and shale of Triassic Hawkesbury Sandstone and Terrigal Formation. Since European settlement in the early 1820s the natural riparian vegetation has been extensively cleared (Erskine *et al.* 2010). The largest catastrophic flood since European settlement occurred in June 1949 and resulted in upstream channel incision and bank instability, with concurrent downstream sedimentation and channel widening (Erskine & Melville 2008; Erskine *et al.* 2010). Based on channel behaviour since European settlement Erskine *et al.* (2010) divided the alluvial section of Dairy Arm into three zones; the upper intact zone, the incised zone and the downstream depositional zone. The reach in this study occurs entirely within the depositional zone and has experienced substantial sedimentation since 1949 because of massive upstream channel erosion by widening and incision (Erskine & Melville 2008).

In March 1978 a catastrophic flood increased the mean bankfull channel width of Dairy Arm by 50% (Erskine *et al.* 2010). In 1982 the then NSW Water Resources Commission commenced river training works for erosion control by planting exotic Willows and Poplars and installing mesh fencing and stock-proof fencing (Figure 2). In 1987 the same government agency planted *Casuarina cunninghamiana* seedlings on the banks of the lower 3.6 km of Dairy Arm (Figure 2); this planting is also considered part of the river training works. These seedlings were not grown from seed, but collected from the nearby Wollombi Brook and transplanted to the banks of Dairy Arm (N. Thompson pers. comm. 2011). Though the exact location of individual plantings could not be obtained from departmental records, the plantings can be

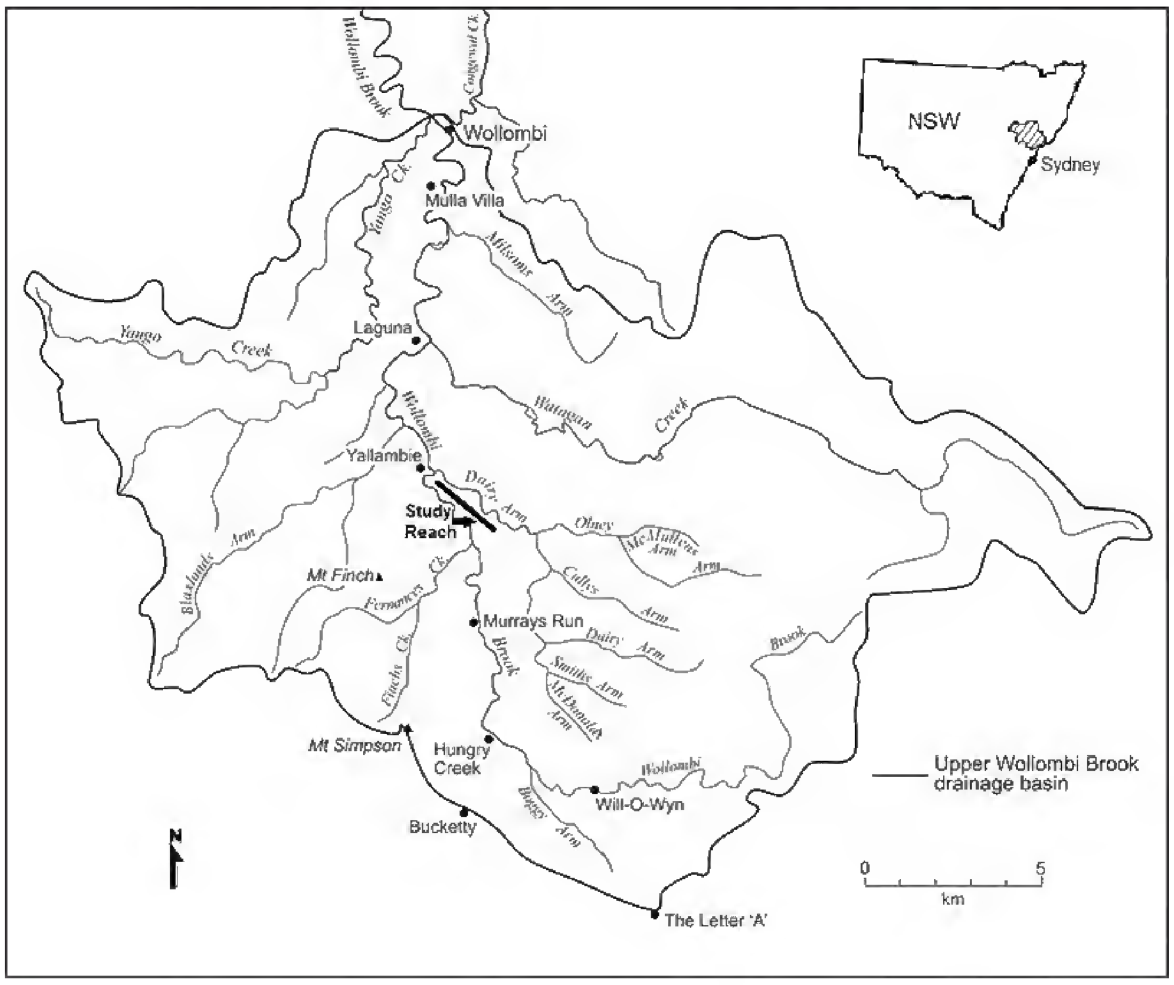

Fig. 1. Location of the study reach along Dairy Arm in the upper Wollombi Brook catchment. Inset:- general location of the Hunter Valley (hatched) within New South Wales (NSW).

easily identified in the field because: (i) they occur as a single line of evenly spaced adults of a similar size; (ii) stands are surrounded by the remnants of rectangular fences; (iii) the third author has been regularly visiting the site to conduct research since 1979; and (iv) an oral history of the site is provided by the current landowner. Note that, as a result of flood damage and the extensive sedimentation that has partially buried them, the river training fences surrounding the stands of trees no longer exclude livestock and all the sites examined in this study were now open to grazing by cattle.

Dairy Arm has a warm-temperate climate with the highest mean maximum temperature of 30° C in January, and the lowest mean maximum of 17.2°C in July (Cessnock Airport; 19 years of record; Bureau of Meteorology). The highest mean minimum temperature of 16.2°C occurs in February, whilst the lowest mean minimum temperature of 4°C occurs in July. Rainfall data were available from the Yallambie Rainfall Station (Station 61205; 51 years of record; Bureau of Meteorology) located about 200 m from the most downstream site investigated (Site 5). The area has a summer

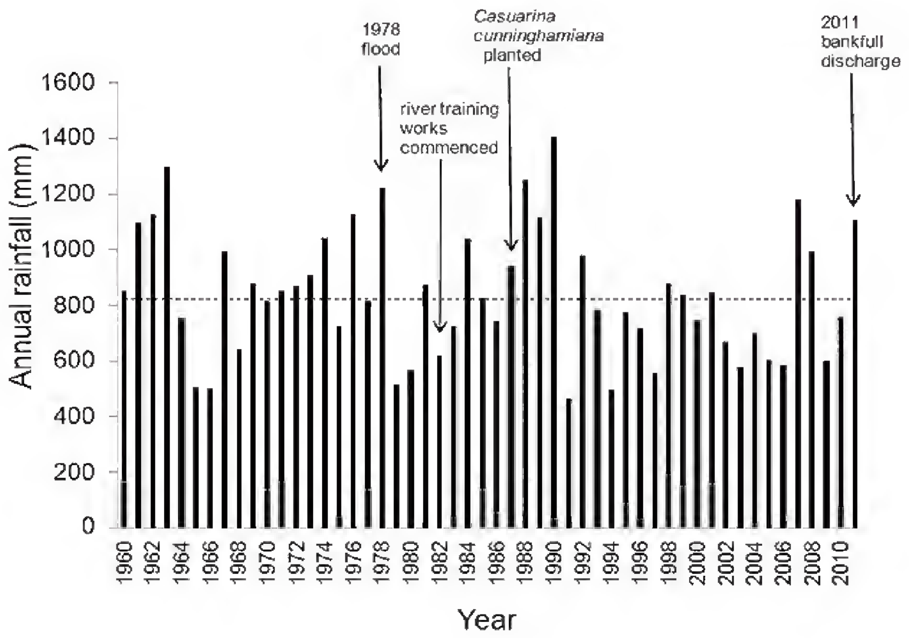

Fig. 2. Annual rainfall (black bars) and the long-term median (dashed line) at Yallambie near Dairy Arm (Station 61205; 51 years of record; Bureau of Meteorology).

Table 1. Return period (years on the annual series) of major storm events based on Yallambie (61205) record in Dairy Arm. Maximum 1-day, 2-day & 3-day rainfall totals (mm) are shown in parentheses.

	Return periods (years)		
Storm event	**1-day duration rainfall**	**2-day duration rainfall**	**3-day duration rainfall**
March 1978	33 (166)	33 (221)	89 (272)
February 1990	15 (113)	15 (173)	15 (204)
June 2007	89 (185)	89 (226)	33 (246)
June 2011	4 (84)	4 (109)	3 (111)

rainfall maximum and the median annual rainfall is 822 mm. The highest mean monthly rainfall occurs in February and the lowest in July. Rainfall in 2011 was well above the long-term median (Figure 2).

There is no river gauging station on Dairy Arm but a bankfull discharge event occurred on Dairy Arm between 12 and 16 June 2011. Bankfull discharge is the maximum discharge that can be contained within the channel without the flow spilling over the banks (Simon *et al*. 2004). Although technically not a flood, because the flow did not overtop the banks (N. Thompson pers. comm. 2011), for the sake of brevity we will use the term flood rather than bankfull discharge. The total rainfall recorded at Yallambie during this 5-day period was 164 mm and the maximum daily rainfall was 84 mm (on 13 June). Based on this rainfall record, intensity-frequency-duration analysis shows that the June 2011 storm had a return period of 3 to 4 years, depending on duration (Table 1). This storm event was much smaller than those that contributed to the large floods of June 2007 and March 1978, both of which have a return period of 33–89 years (Table 1). In comparison, the February 1990 flood was associated with a storm event that has a return period of about 15 years (Table 1).

The composition of the remnant vegetation along the study reach is consistent with Wollombi Alluvial Red Gum – Apple Forest (as defined by Peake 2006), a tall open forest (12–25 m) with 10–15% cover. In this vegetation community *Casuarina cunninghamiana* typically occurs along river banks of high energy, where it is usually the only tree present (Peake 2006). However, in Dairy Arm, *Casuarina cunninghamiana* had been completely eradicated from the riparian corridor by 1979 (when we first started researching Dairy Arm) and the present population is the result of the plantings in 1987. We have not observed any *Casuarina cunninghamiana* on the upstream part of Dairy Arm, nor on its upstream tributaries. However, this species does occur downstream of the study site on Wollombi Brook. The main other woody species observed on the banks and the floodplain of the study reach include *Acacia parvipinnula* (Silver-stemmed Wattle), *Angophora floribunda* (Rough-barked Apple), *Eucalyptus amplifolia* var. *amplifolia* (Cabbage Gum) and *Melaleuca decora*.

Methods

We chose five sites along Dairy Arm, based on existing stands of *Casuarina cunninghamiana* planted in 1987, counted the number of trees in each of the five stands, and walked a transect along the banks of Dairy Arm to establish whether any isolated adult trees (or saplings) existed between the fenced stands. Only two additional trees were found, and despite the absence of fencing, their size and the fact that they occurred on the bank < 20m downstream of a line of Poplars and Willows was consistent with them having been planted in 1987. These two trees were included in the calculation of the long-term survival rate. We measured the maximum height of each stand and the diameter at breast height (dbh) of each tree to determine the size class distribution of the surviving population. For each tree we recorded the presence/absence of fruit to determine the proportion of the population that was potentially producing seed. There were no seedlings (< 1.5 m) on the floodplain and seedlings were extremely rare on the high benches. To determine the survival response to a bankfull discharge *Casuarina cunninghamiana* densities were only measured within the channel.

At each site we used three 10 m x 10 m quadrats placed within the channel. Use of a 10 m x 10 m quadrat meant that the fluvial landforms sampled typically included the bed (covered with water), mid-stream and bank-attached bars and low benches (Erskine & Livingstone 1999). We positioned the three quadrats so that the first quadrat was 20 m upstream of the canopy edge of the adult stand, the second quadrat was placed at the mid-point of the stand length and the third quadrat was positioned 20 m downstream of the canopy edge of the stand. We measured the bankfull width of the channel; the mid-point of the channel width became the centre point of each 10 x 10 m quadrat. We had to alter the method at site 4 because, instead of one stand, there were two small stands separated by a relatively small gap (98 m). In this case, we set the first quadrat 20 m from the upstream canopy edge of the stand furthest upstream while the third quadrat was set up 20 m from the canopy edge of the stand furthest downstream. To avoid the potential influence of the gap, we randomly selected one of the stands and set up the “second” quadrat adjacent to the mid-point of that (upstream) stand. In each quadrat we visually estimated the percentage cover of bare ground, water and ground layer vegetation, counted the number of *Casuarina cunninghamiana* individuals and measured their height. As the tallest individual measured in the quadrats was 1.17 m, density in the channel will hereafter be referred to as seedling density. For each individual, we recorded evidence of being grazed or partially buried. Partial burial was recorded as present when the root collar of the seedling was at least 1 cm below the ground surface. In quadrats where density was high, we divided the quadrat into 1 m or 2 m strips to ensure a high accuracy of counts. The pre-flood data were collected between 7 and 10 June 2011 and the post-flood data were collected between 5 and 10 August 2011, about eight weeks after the flood. We placed the quadrats in the same location before and after flood.

We collected bed sediment at five cross sections evenly spaced through the depositional zone of Dairy Arm. On each section six equi-spaced points were bulked for each sample. The samples were oven-dried, weighed and a 100 g sub-sample, obtained by cone and quartering, was sieved through a nest of stainless sieves.

Shapiro-Wilk tests revealed that both the pre-flood ($W = 0.50$; $p < 0.0001$) and post-flood ($W = 0.62$; $p < 0.0001$) density data were highly skewed. Both logarithmic and square root transformations failed to improve normality and therefore we used a non-parametric Wilcoxon signed rank test (Sokal & Rohlf 1995) to compare density in the channel, before and after flood. Seedling density measured in the middle quadrat at Site 4 was an outlier (353 seedlings in 100 m^2), so we removed this point when conducting spearman correlations between seedling number, bare ground and vegetation cover. Paired t-tests were conducted on square root transformed data, to test for a difference in bare ground, vegetation cover and channel width before and after flood. As transformation did not improve the normality of the seedling burial data, we used a non-parametric Wilcoxon signed rank test for paired samples (Sokal & Rohlf 1995). We used Predictive Analytical Software (PASW) version 18 (Norušis 2010) or JMP version 8 (SAS Institute 2008) for all analyses.

Results

Long-term survival rate

The survival rate of the *Casuarina cunninghamiana* seedlings planted in 1987 was 24% over the 24 year period (72 of 300 planted seedlings surviving). The surviving population had a mean diameter at breast height of 31.5 cm (± 1.87 cm SE) and a bell-shaped size distribution (Figure 3). The adult stands ranged from 37 to 147 m in length and consisted of 4–23 individuals with an average canopy height of 18 m (± 1.3 m SE). All stands consisted of a single line of trees located just before the start of the floodplain and usually (the exception being Site 1) with a high bench having formed on the channel side of the planting since the construction of the river training works (Erskine *et al.,* 2010). 58% of the adult trees were producing fruit.

Survival response to the June 2011 flood

Following the flood the median density of seedlings within the channel decreased significantly from 12 seedlings per 100 m^2 (inter-quartile range = 58) before the flood to 2 seedlings per 100 m^2 (inter-quartile range = 7) after flood; this difference in density was significant (d.f. = 14; W= - 30; p = 0.0024) with the Wilcoxon signed rank test. Seedling loss was the result of both flood scour and burial by sediment. Prior to the flood the majority of seedlings were less than 30 cm tall (Figure 4) and few seedlings were greater than 46 cm in height. Seedling survival after the flood varied with height class (Figure 4). Seedling survivorship tended to increase as the height of the seedlings increased, e.g. only 9% of seedlings < 5 cm tall survived, whilst 30% of seedlings in the 31–45 cm height class survived the bankfull flood (Figure 4). Seedling survivorship in the > 76 cm height class was >100% and is most likely explained by two seedlings being missed in the pre-flood sampling.

As the "seedling" class measured here could include individuals up to 1.2 m tall, those few individuals in the larger size classes may be up to 1–2 years old, especially if grazed.

The Wilcoxon signed rank test showed that the percentage of seedlings partially buried by sediment was significantly higher (d.f. = 14; W = 13; p = 0.016) after the flood compared to before the flood (Table 2). The variability in the seedling burial data was partly due to a distinct difference between sites. Sites 1 and 2 showed no evidence of partial burial of seedlings before or after the flood, while at the more downstream sites (4 and 5) a small proportion (about 1–5%)

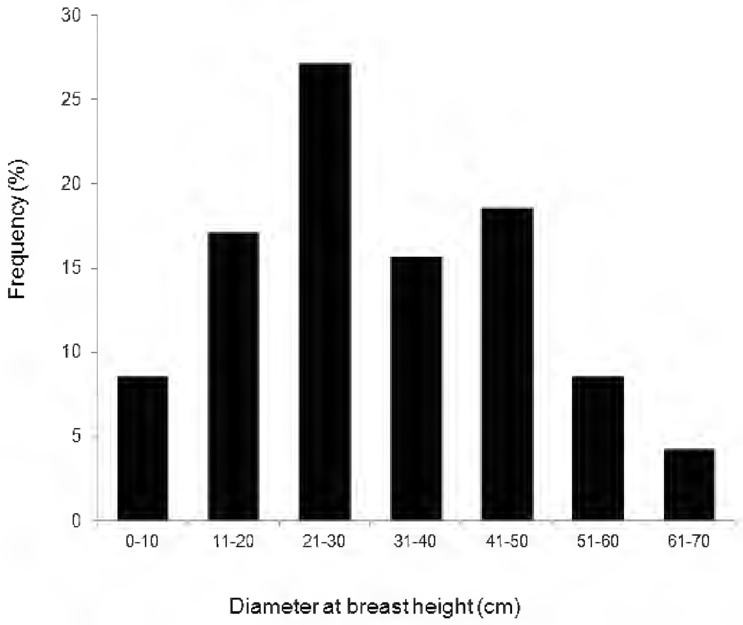

Fig. 3. Diameter size class distribution of the surviving 24 year old *Casuarina cunninghamiana* population in 2011, originally planted on the banks of Dairy Arm in 1987. Population mean dbh is 31.5 cm (± 1.87 cm SE) (n=72).

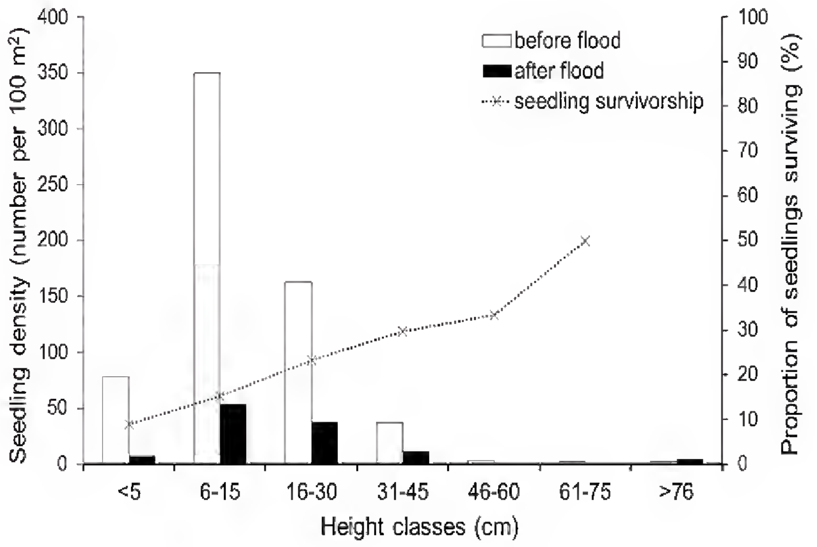

Fig. 4. Height class distribution of *Casuarina cunninghamiana* seedlings in 100 m^2 quadrats within the channel of Dairy Arm before and after the June 2011 bankfull flood and the proportion of seedlings surviving the flood (n = 15) (dotted line).

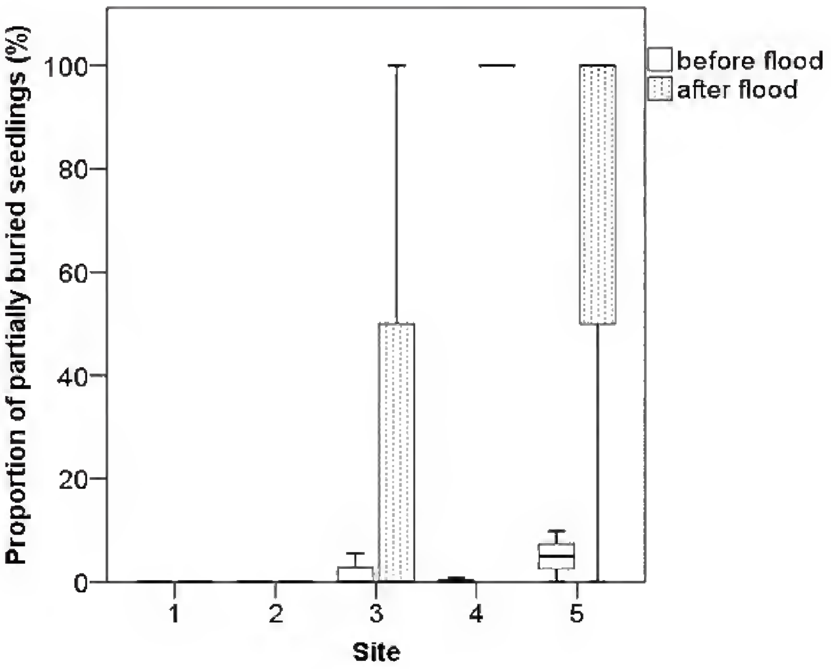

Fig. 5. Proportion of *Casuarina cunninghamiana* seedlings in the channel that were partially buried by sediment, before and after the June 2011 bankfull flood at each of the five study sites (n =3).

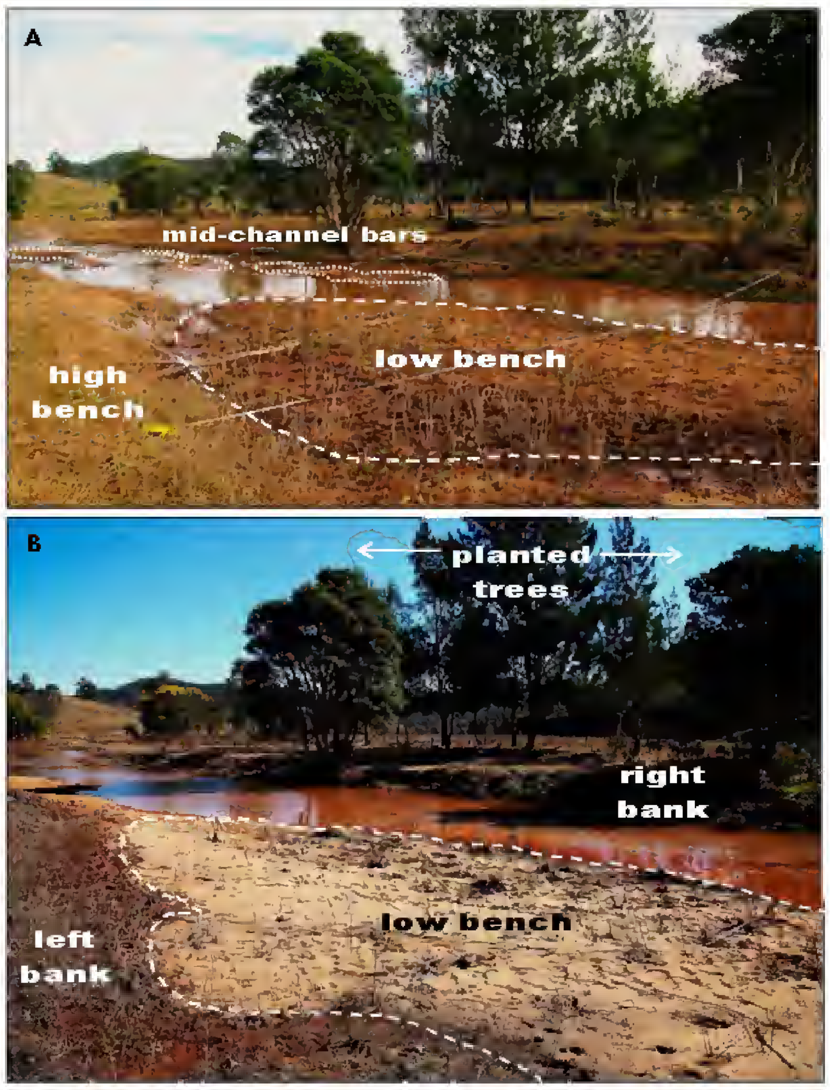

Fig. 6. Photos of the channel at Site 4 on Dairy Arm in 2011, looking downstream (A) immediately before, and (B) 8 weeks after bankfull flood. The 1987 planted trees are in the background. Photos: A. Chalmers (7 June 2011) & F. Erskine (5 August 2011).

were partially buried before the flood and 100% of seedlings were partially buried after the flood (Figure 5). Spearman correlations showed that mean seedling density in the channel prior to the flood was significantly positively correlated with the mean percentage of bare ground (r = 0.61; p = 0.02), but this relationship was no longer significant after flood (r = 0.18; p = 0.53). There was no significant relationship between seedling density and percentage of vegetation cover, either before the flood (r = -0.2; p= 0.38) or after the flood (r = 0.29; p = 0.30). 37% of the seedlings within the channel showed evidence of grazing (Table 2).

Table 2. Mean (± SE) percentages of bare ground, vegetation cover, grazed & partially buried ***Casuarina cunninghamiana*** **seedlings and channel width at Dairy Arm (n = 15) before and after the June 2011 bankfull flood.**

	Before flood	**After flood**
Bare ground (%)	26 ± 5.1	30 ± 5.7
Vegetation cover (%)	32 ± 5.5	21 ± 3.5
Grazed seedlings (%)	37 ± 12.9	Not determ.
Buried seedlings (%)	1.9 ± 0.58	60 ± 16.3
Channel width (m)	8.1 ± 0.91	10.2 ± 0.86

Channel response to the June 2011 flood

Channel width was significantly greater (d.f. = 14; t = -2.8; p = 0.014) after flood compared to before flood (Table 2). Percentage of bare ground (i.e. bare sediment) was not significantly different (d.f. = 14; t = -0.22; p = 0.83) before and after flood (Table 2). Note that percentage of bare ground has probably been underestimated here, as the method did not include bare sediment covered by water, which was greater during the sampling period after flood. Vegetation cover was lower after flood compared to before flood (Table 1), but this difference was not significant (d.f. = 14; t = 2.1 ; p = 0.055). Paired photos taken at Site 4 provide an example of landforms typically found in the channel of the depositional zone of Dairy Arm and how these landforms were affected by the flood (Figure 6). Site 4 had the greatest mean density of seedlings in this study, and this site had both mid-channel bars (adjacent to *Melaleuca decora* in the background) and a large low bench (in the foreground) that was partially vegetated before the flood (Figure 6a). The mid-channel bars were removed by the flood and a fresh layer of sand was deposited on the low bench attached to the left bank of the stream (Figure 6b). A large proportion (89%) of the seedlings in this particular quadrat (mainly on the low bench) were either removed by scour or buried by sand.

The median bed sediment size was consistently between 0.22 and 0.25 mm in diameter at all cross sections. The sand was always moulded into an asymmetrical small-scale ripple with a steeper stoss than lee slope.

Discussion

Quantification of survival rates is needed if we are to fully understand the population dynamics of riparian species and design more successful restoration programs. Erskine *et al.* (2009) proposed that *Casuarina cunninghamiana* seedlings in the bed and on low bars of sand-bed streams would be periodically removed by high flows but they were unable to provide direct evidence that this occurred. The current study confirms that while lower elevation fluvial landforms are ideal habitats for germination, up to 90% of seedlings may be lost in some locations as a result of a bankfull flood.

According to Simon *et al.* (2004), bankfull discharge has sufficient velocity to alter the river bed of sand-bed streams. The increase in channel width confirms that the river bed of Dairy Arm was altered by the bankfull event, but surprisingly bare ground and vegetation cover within the channel were not substantially altered. Nevertheless, paired photographs illustrate that at some locations mid-channel bars were removed and sediment was deposited on low benches within the channel.

We also found that a bankfull flood was sufficient to remove (or bury) many, but not all, of the *Casuarina* seedlings growing within the channel. Of those seedlings that survived the flood, about 60% were partially buried. This is not surprising because the median grain size of the bed material on Dairy Arm in the study area is 0.22–0.25 mm and is transported by nearly all discharges. How well, or for how long, seedlings can tolerate partial burial or recover from complete burial is currently unknown. Anecdotal observations in this study indicated that some seedlings just visible above the deposited sediment had not survived. Species that occur in similar environments to *Casuarina cunninghamiana*, such as Poplars and Willows have been found to succumb to burial (Johnson 1994; Scott *et al.* 1996). The study reach is within the depositional zone of Dairy Arm and has experienced substantial sedimentation since 1949 because of massive upstream channel erosion (Erskine & Melville 2008). Erskine *et al.* (2010) show that medium sand has been slowly moving downstream; the upstream supply is now being reduced as it becomes exhausted and the sand remaining in storage within the channel is stabilised by vegetation (particularly by grasses). As the supply of sand to the lower reach of Dairy Arm (e.g. sites 4 and 5) reduces, we would expect that seedling survival will increase.

In the only other study to quantify survival rates of *Casuarina cunninghamiana*, Chalmers *et al.* (2009) found that 3–30% of young adult trees (13 m in height) were removed from benches at Widden Brook during an overbank flood (in June 2007). Our results confirm that scouring by bankfull discharge events, which may occur every 3 to 4 years, is a barrier to re-instating self-sustaining populations of *Casuarina cunninghamiana* on streams that have been previously cleared of riparian vegetation. As most riparian restoration practitioners know through experience, any technique that can reduce the impacts of scouring will improve restoration outcomes which is why the long-stem planting technique is recommended by a number of restoration practitioners (Hicks *et al.* 1999; Peel 2010) for use in riparian zones.

Seedling loss in the current study was due to flood scour or burial; there was no evidence of impacts from inundation. Woolfrey & Ladd (2001) found that continuous submergence of at least 2 months eliminated *Casuarina cunninghamiana* seedlings in the channel of the Murrumbidgee River, but wading depths observed during sampling in Dairy Arm suggested that stream height was almost back to pre-flood conditions after 7½ weeks – consistent with the duration of inundation being too short to affect survival.

Prior to the bankfull flood, the height class distribution of seedlings suggested that regeneration within the channel of Dairy Arm is episodic, rather than continuous, as many seedlings were about the same height. Episodic recruitment occurs when abundant seed release coincides with favourable habitat and climatic conditions (League & Veblen 2006). Based on the even-aged stands regenerating on benches, Erskine *et al.* (2009) concluded that establishment of *Casuarina cunninghamiana* within the channel of Widden Brook is episodic. The positive relationship between seedling density and percentage bare ground within the channel found here is consistent with other studies on the regeneration of exotic pioneer riparian tree species (Bradley & Smith 1986; Cremer *et al.* 1995) and *Casuarina cunninghamiana* (Woolfrey & Ladd 2001). However, our results suggest that this relationship may no longer be evident if sampling occurs shortly after a flood that is sufficiently large to alter the bed. The change in the height distribution before and after the bankfull flood shows that a greater proportion of smaller seedlings (< 15 cm) were removed or buried. Presumably larger seedlings are better able to resist high flows, by having a more developed root system that anchors them to the bed, and their greater height would reduce the risk of being completely buried. Thus, the size class distribution will not only reflect establishment events, but the episodic nature of loss due to floods.

In May 1982 exotic Willow and Poplar plantings and extensive stock-proof fencing were installed in Dairy Arm (Erskine *et al.* 2010), and 300 *Casuarina cunninghamiana* seedlings were planted five years later (month of planting unknown) by the same government agency. The bell-shaped size distribution of the surviving population is consistent with the trees being established at the same time. 24% of these remain 24 years later and just over half of them produced fruit in 2011; a survival rate within the range found by previous studies of planted riparian trees and shrubs. Webb *et al.* (1999) found survival rates of tree species that typically occur in riparian habitats along sand-bed streams in the Hunter Valley ranged from 33% (*Angophora floribunda*) to 89% (*Eucalyptus camaldulensis*) (measured14 years after being planted). Unfortunately there is no comparative data for *Casuarina cunninghamiana* survival because this species was not usually planted as part of river training works at that time, despite its widespread distribution in the region (Webb *et al.* 1999). However Hicks *et al.* (1999), reporting on the survival of four riparian tree species planted at two sites in the Hunter Valley, compared the performance of long-stem and standard tube-stock and included *Casuarina cunninghamiana*. Eleven months after planting, 69% of the long-stem plants had survived compared to 19% of those planted as standard tube-stock. Thus the survival rate of the standard tube-stock in their study is similar to the survival rate reported here.

In contrast to the survival rate after the June 2011 flood (which isolates the impact of a discrete disturbance event), the long-term survival rate integrates the potential effects of floods, droughts, sedimentation and grazing. The 1987 seedlings used for river training works were apparently obtained from neighbouring Wollombi Brook and transplanted to the banks of Dairy Arm (N. Thompson pers. comm. 2011). The mean annual rainfall at Dairy Arm (at Yallambie) between 1959 and 1990 was about 16% higher than between 1991–2008 (Erskine *et al.* 2010) (Figure 2). Being planted on the banks of an over-widened channel just at the end of a relatively wet period would have increased the chances of the planted seedlings becoming established, as water stress was probably low in the early stages of establishment (Figure 2). At least some of the plants survived the moderate-sized flood that occurred when the planting was only 3 years old (i.e. February 1990). In the absence of catastrophic floods during this period (Erskine *et al.* 2010) vegetated benches built up in the channel over time, so that by the time the large overbank flood occurred in June 2007 (Erskine & Chalmers 2009; Erskine *et al.* 2010) the planted trees were protected from scouring by a bench. Though originally protected by fencing, these had largely gone by 2011 and we found that 37% of the seedlings had been grazed. The benefit of stock-proof fencing on seedling abundance has been previously reported by Chalmers *et al.* (2006). Therefore the exclusion of livestock from the banks of Dairy Arm, during the crucial period of establishment, would have also increased the probability of seedlings reaching adulthood. Ganger records show that maintenance and repairs to the stock-proof fencing on Dairy Arm was undertaken by the then DLWC on at least six occasions between 1982 and 1997. Clearly, one-off incentive funding from government agencies for the installation of stock-proof fencing along riparian zones is likely to be inadequate because considerable repair costs due to flood damage can be expected over the life of any restoration or conservation project.

Conclusions and management implications

We found that only a small proportion of the naturally recruiting seedlings growing within the channel survived a bankfull flood and that a flood of this size can significantly increase the channel width of a sand-bed stream (at least where the vegetation on bars and low benches is predominately herbaceous). Fluvial geomorphic processes associated with a bankfull flood clearly affect the survival of *Casuariana cunninghamiana* seedlings, with seedling loss being due to scour and burial by sand. The high proportion of seedlings that were partially buried by sediment in this study is consistent with the reach being located in the deposition zone of Dairy Arm where highly mobile medium sand is slowly moving downstream. As sand-bed streams tend to be re-worked more often, and on a larger scale than other bed sediment types (Erskine 1996; Brierley and Fryirs, 2005; Erskine *et al.* 2010), the conclusions of this study are unlikely to apply to *Casuarina cunninghamiana* growing in bedrock or gravel-bed streams or to regions with different climatic and rainfall regimes.

However under the climatic conditions of the last 24 years, seedlings planted on the banks of Dairy Arm in 1987 were able to survive through to adulthood and supply viable seed to the channel. The rate of survival was low, but consistent with other studies of riparian species (Hicks *et al.* 1999; Webb *et al.* 1999) used in river training works in the Hunter Valley. Long-stem planting may improve survival by reducing both the risk of removal and burial by flood (Hicks *et al.* 1999) but further quantitative, longer-term and better designed studies on this planting technique are needed. Where standard tube-stock is planted, our results suggest that seedlings > 15 cm in height may have an improved chance of surviving a bankfull flood. The exclusion of livestock from the banks and the channel is recommended to allow both planted and naturally regenerating seedlings to establish and reach maturity. Whilst permanent exclusion is clearly preferable (to allow the restoration of the understorey as well), a compromise would be to exclude livestock for at least 4–5 years or until most of the crown of the saplings is above the reach of grazing animals. Intermittent grazing with low stocking densities could then be used to control pasture grasses and weeds, where necessary.

Sand-bed streams in the region are still recovering from the combined effects of clearing by European settlers and post-European catastrophic floods (Erskine 1996; 2008; Erskine and Chalmers 2009; Erskine *et al.* 2010). For sand-bed streams with a large supply of sediment within the channel, high losses of seedlings through burial can be expected for some time yet. However ongoing research is showing the value of re-establishing vegetation along these channels, as formerly unstable channels are becoming more resilient to relatively large floods as a result of vegetation colonisation (Erskine 2008; Erskine and Chalmers 2009; Erskine *et al.* 2010).

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Adventures, hardship and a scientific legacy: Ludwig Leichhardt's 1843 journey to Mt Royal in the Hunter Valley, NSW

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Abstract: In January 1843, curiosity for natural history led a young German naturalist, Ludwig Leichhardt, to spend about three weeks exploring Mt Royal on the north of the Hunter Valley, about 70 km north west of Newcastle, New South Wales. This was a sidetrack on his journey from Newcastle, through the Hunter Valley and inland to Moreton Bay (Brisbane) and preceded the journeys for which he was to become famous; his 1844–45 overland journey from Moreton Bay to Port Essington (in Northern Territory) and his disappearance without trace in 1848 attempting to cross Australia.

Using his *Diary* and herbarium records this paper brings together the chronological events of the 29 year old Leichhardt's journey, the plant and animal species recorded, the specimens collected and his landscape descriptions and compares the 1843 landscape with the area today. Most of it is now in Mount Royal National Park, and part of the Gondwana Rainforest Reserves World Heritage Area. Using Mt Royal as an example of the richness of Leichhardt's scientific legacy, we draw attention to the existence of a considerable number of Leichhardt's plant specimens in herbaria in Sydney and Melbourne relating to his early collecting around Sydney and the little-known journey from Newcastle to Moreton Bay.

Leichhardt's visit to Mt Royal provides an insight into a gifted young naturalist coping with some of the hardships of nineteenth century botanical exploration, in a landscape which is easily recognizable and of which much is remarkably little changed since European settlement.

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Introduction

Ludwig Leichhardt is one of nineteenth century Australia's iconic bushman explorers; famous for his 1845 overland expedition from Moreton Bay to Port Essington, and subsequent disappearance attempting to cross the continent. Myths have arisen around a man whose chief aim was to make a significant contribution to science, and whose scientific work was highly regarded by his contemporaries. "*Geologists and botanists valued Leichhardt's collections of specimens and the records of his observations which, in an age accustomed to extravagant travellers' tales, were remarkable for their restraint and accuracy; he believed that as long as the traveller was truthful the scientist at home would be thankful to him. Leichhardt was a most dedicated servant of science and from this very dedication sprang a singleness of purpose which shaped his life, and made him somewhat ruthlessly regardless of all but his research. With perseverance, energy, courage and complete disregard of discomfort, and of the physical handicap of poor eyesight, he pursued his goals as 'an explorer of nature'* " (Erdos 1967).

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Leichhardt arrived in Sydney in February 1842 and, with his new friend Lieutenant Robert Lynd, with whom he planned to produce a book on the flora of Sydney, began plant collecting around Sydney. On an excursion to the Botany Marshes in May 1842 he collected *Symphionema paludosum* (LL148) and *Corybas fimbriatus,* his earliest surviving Australian plant collections (Fensham et al. 2006).

He sailed to Newcastle beginning his first and relatively little-known journey, up into the Hunter Valley, then north to New England and on to Moreton Bay (now Brisbane). Unlike his later expeditions this was mostly through established grazing properties; he travelled alone, on horseback or on foot. Between September 1842 and March 1843 he spent about six months in the Hunter region. In Newcastle he stayed with businessman Alexander Walker Scott at Ash Island in the Hunter River estuary. Scott was interested in butterflies, and father of the natural history illustrators Helena and Harriet Scott. At the time of Leichhardt's visit, the Scott sisters were about 10 and 11 years old; only three years later they started their paintings to illustrate *Australian Lepidoptera* (Scott 1864), the first book on Australian butterflies. Scott's manuscript for *Lepidoptera* notes that "*the caterpillar of (Ptilocephala leichhardtii) was first presented to us by Dr Ludwig Leichhardt, in November, 1842, at which time we were much engaged together in the pursuit of Natural History, his attention however being principally directed towards the Botanical riches of the Colony ....*".

From Ash Island, Leichhardt rode to *Glendon*, a large property (about 80,000 acres grazing cattle and sheep) on the Hunter River about 10 km east of Singleton owned by Helenus Scott, brother of AW Scott, where he stayed as a guest. From here he was to spend about three weeks exploring the Mt Royal area to the northeast. Most of this area is now in Mount Royal National Park, and partly within the Gondwana Rainforest Reserves World Heritage Area. What prompted the visit to Mt Royal remains uncertain but in a letter written at *Glendon* on 16 January 1843 he wrote to Robert Lynd, "*I am again as I was from the first moment I saw the blue distant hills, continually striving to get to them and over them ..... At present, these new mountains are before me, the Wollombi Range, Dyrinne* [Mt Dyrring] *and Mt Royal. I visited the Paterson and Allan River and they carried such a quantity of basaltic pebbles, that I hope to find at Mt Royal a good lump of basalt.*" (Aurousseau 1968 p626).

At Mount Royal his enthusiasm for collecting rainforest plants (as specimens for colleagues and material for future publications) and his careful observations of the landscape and geology coincided to produce a valuable record of the landscape at that time, and an intriguing story filled with the pitfalls and perils of nineteenth century scientific collecting. Writing to Walker Scott on 15 February 1843, he described how he had "*lived a hermits life for about 3 weeks at Mt Royal, the geology of which as well as the brush of its easterly flancs yielded me a rich harvest of interesting objects. ..... I was between the horns of a wild bull, I was almost burnt to death in a hollow tree – so I hope to become seasoned for the interior.*" (Aurousseau 1968 p627)

Our project aimed to compile the story of Ludwig Leichhardt's three weeks at Mt Royal, to locate his likely routes, and to integrate his written observations with information from his plant specimens (which have not been previously looked at in an environmental context). The story provides a picture of the young Leichhardt as an active scientist and important information about the past and present landscape in particular locations visited by Leichhardt.

Ludwig Leichhardt (1813–1848?)

Friedrich Wilhelm Ludwig Leichhardt was born in Germany in October 1813 and developed an interest in natural history while studying at university in Germany and later in England. In October 1841 he sailed for Australia with the expressed intention of exploring Australia's inland (Erdos 1967). His overland journey from Newcastle to Moreton Bay in 1843 was followed by a return to Sydney to arrange his collections of plant and rock specimens and to work on the notes of his observations.

He sailed from Sydney in 1844 to lead an expedition from Moreton Bay to Port Essington; he completed the overland journey of some 4,800 km in December 1845, and subsequently planned a further expedition to cross Australia from Moreton Bay to the west coast. After difficulties and delays, this journey commenced in February 1848 but the expedition disappeared without trace later that year.

Leichhardt left many records of his observations in Australia in his diaries, letters, notebooks, sketch-books, maps, and published works. Recent biographies of Leichhardt include Bailey (2011) and Finger (2013); his story has also been variously interpreted in literary works expressing widely differing views about his achievements, character and contributions.

Methods

Mt Royal (lat 32° 10' S, long 151° 20' E) is at the southern end of the Mt Royal Range on the north side of the Hunter Valley about 70 km north west of Newcastle. All references to localities, landscape features, and plant species in the Leichhardt material in the Mitchell Library (State Library of NSW) in Sydney covering the time he spent in the Mt Royal area in 1843 were collated. These included Leichhardt's *Diary*, written in English and German, notebooks written in English, French and German and his published letters (Aurousseau 1968), his description of the geology of Mt Royal published in Germany (Leichhardt 1855) and translated from German by the senior author, and a transcription and translation of German text in his *Diary* for the period January to March 1843 (Darragh & Fensham 2013).

Database records of herbarium specimens collected by Leichhardt in the Mt Royal area were sought from state herbaria in Sydney and Melbourne. In the National Herbarium of NSW (coded NSW) database were records of 22 plant specimens; 17 were located in the collection and photographed. Leichhardt's handwritten labels on some of the specimens provided further information on their original collecting site. Details from another 40 specimen records were obtained from the National Herbarium of Victoria (coded MEL) database in Melbourne.

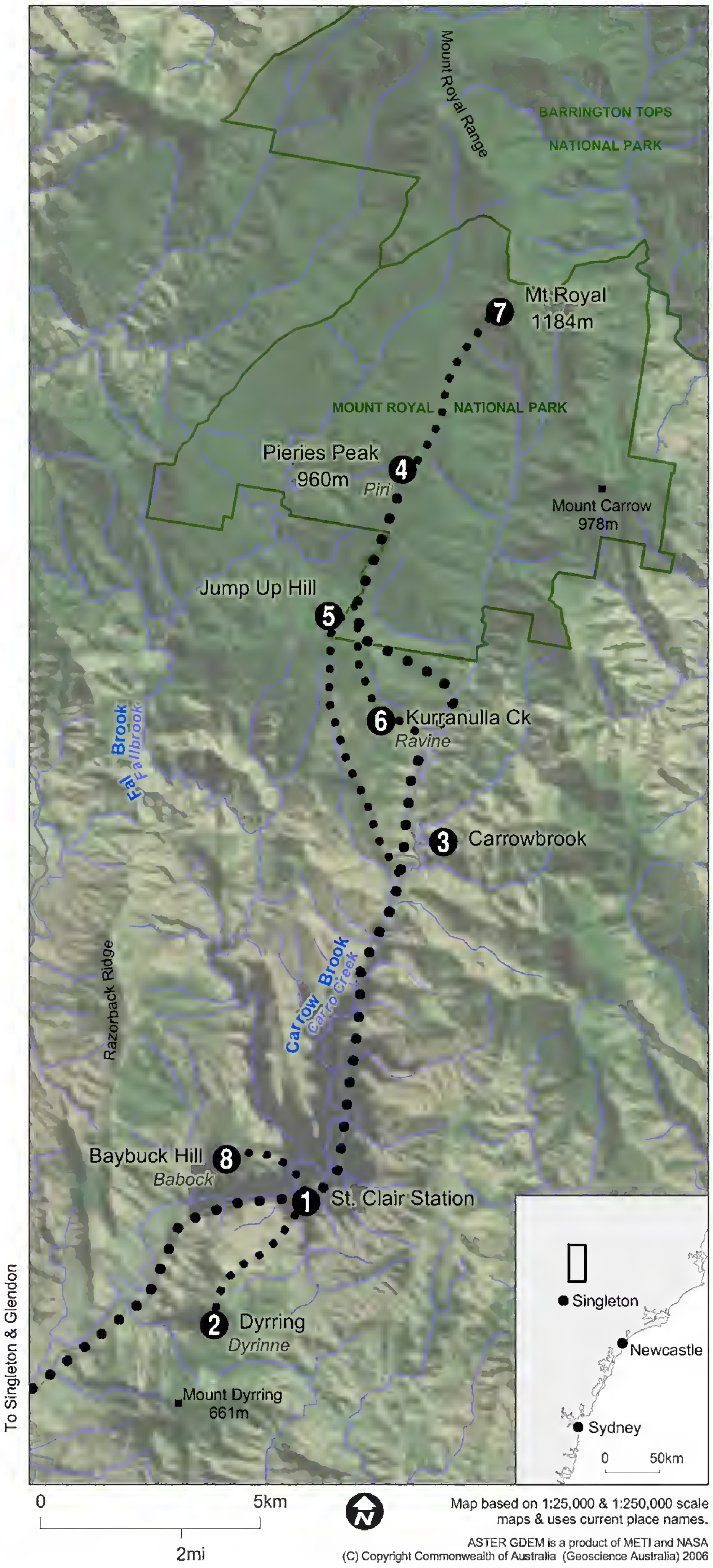
To identify his collecting locations in the field and compare his landscape descriptions with the currently existing vegetation it was important to identify his routes. Because events are often referred to out of sequence in the *Diary*, and separately referred to in a number of letters, compiling the chronology of events was a challenge. The senior author's local knowledge of the Mt Royal area allowed him to identify particular localities, and site visits were undertaken to check the text references and confirm the likely chronology. Additional material used included maps from the time of Leichhardt's visit, early parish and portion maps showing survey descriptions, and the earliest available aerial photographs (from 1939) of the area.

To check place names and review references that might provide relevant information, discussions were held with members of Singleton Historical Society and others. Contemporary information includes vegetation descriptions and maps prepared by the Forestry Commission of NSW and the NSW National Parks & Wildlife Service Plan of Management for Mt Royal National Park.

The average annual rainfall at Mt Royal is around 1400 mm but is highly variable due to local topographic variation (Bridgman 1984). During summer, south easterly winds are common and bring moist air and low cloud from the coast and influences the distribution of vegetation with open Eucalypt forests on the drier western slopes and rainforests found in gullies and slopes having a south to easterly aspect.

The weather conditions significantly influenced Leichhardt's activities and as frequently reported in his *Diary* affected his movements, the plants that were observed, and the conditions under which his plant collecting and drying occurred. Weather records published in the *Maitland Mercury* and *Sydney Morning Herald* for January–February 1843 were extracted using weekly weather reports from the towns of Maitland, Singleton, Wollombi and Scone, relatively close to Mt Royal, and compared with the daily Sydney reports to indicate the regional conditions (Appendix 2). Weather observations in the *Diary* and contemporary newspaper reports for Sydney and the Hunter Valley show general consistency and were compiled to provide context for interpreting Leichhardt's descriptions of particular events.

The Mt Royal excursion was a side trip for Leichhardt, away from the Hunter River where by 1843 most of the pastoral settlement had occurred and where Patricks Plains (now the town of Singleton) had been settled by Europeans 20 years earlier. Contemporary events according to the *Maitland Mercury* newspaper, which had commenced publication a short time before Leichhardt's visit, included periodic bushranging on the road to Singleton, bands of roaming Aboriginal groups, the highly important agricultural and commodity prices, and commercial and political happenings.



Map based on 1:25,000 & 1:250,000 scale maps & uses current place names.
ASTER GDEM is a product of METI and NASA
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Fig. 1. Mt Royal locality map showing current location names, terrain, Leichhardt's likely routes and current vegetation cover. Names referred to by Leichhardt are shown in italics after current names. Route numbers correspond with known locations and are in chronological order. Leichhardts camp was located a short distance south of location 4, the sawyers hut was between locations 4 and 5, and Glennies Stockyard is south of location 3.

Table 1 Current and past place names in the Mt Royal area mentioned by Leichhardt

Leichhardt is likely to have had access to Thomas Mitchell's 1834 map of the colony (Mitchell 1834) which named some of the geographical features at Mt Royal. Leichhardt's *Diary* appears to be the first documentation of some place names such as *Piri* and *Jump Up Hill,* many of which are likely to have their origin from the Wonaruah Aboriginal people.

Current name	Past names	Comments
Mount Dyrring	Dyrinne, Deren, Dyring	Named and identified in Mitchell's map, possibly in incorrect location
Carrow Brook	Carro Creek, Carrocreek, Busby's Creek	Noted on Mitchell's map
Pieries Peak	Piri	
Mount Royal		Named and identified in Mitchell's map
Fal Brook	Fallbrook	Noted on Mitchell's map
Baybuck Hill	Babock, Bibock, Babuck, Bubock, Bebock	
Mt Carrow	Carrow	Named and identified in Mitchell's map
No name	Jump Up Hill	Northern ridge is named as Jump Spur

Results

Likely routes used by Leichhardt are shown in Figure 1; Table 1 shows a comparison of some of his place names.

Leichhardt's time at Mt Royal

Following his stay near Newcastle, Leichhardt travelled to *Glendon* near Singleton which he used as a base for his Mt Royal explorations. He arrived at *Glendon* on 20 December 1842 where he spent time observing the wildlife and geology. He refers to native animals seen at *Glendon*, including possums, native cats, kangaroo rat and kangaroo and familiarised himself with the grassland plants in the Eucalypt woodland. His explorations included a dramatic attack by a bull, in which he lost his geological hammer and escaped shaken and trembling, but otherwise unscathed.

In the weeks leading up to his arrival at *Glendon*, the countryside had been dry with few streams flowing. In a letter to his brother-in-law on 16 January 1843, Leichhardt observed that "*The drought has persisted for an extraordinary time, and there was scarcely enough grass on the vaunted banks of Hunter's River to provide my horse with scanty meals.*" (Aurousseau 1968 p618)

In reporting the previous week's weather from Wollombi, the Maitland Mercury (of 21 January 1843) observed "*On some days a heavy, lowering sky raised hopes, only to be disappointed, of an immediate and heavy fall of rain; this has been followed quickly by a scorching heat, that has as rapidly changed in a few hours to cool, bracing weather. This variable temperature has had a very trying effect upon the health of delicate persons, and the vegetation begins to wear a sickly appearance for wont of rain.*" It was through a hot, harsh and barren landscape that Leichhardt made his journey to the lush rainforest at Mt Royal.

St Clair, January 1843

On 24 January 1843, on a dry slightly cloudy day with east to south-easterly breezes, Leichhardt rode to *St Clair* homestead (now flooded by the Lake St Clair dam), a journey of some 32 km (20 miles) across what would then have been a dry open Eucalypt woodland landscape with an occasional herd of sheep or cattle accompanied by a shepherd. His journey was in the company of an old sawyer "*who had cut timber for more than nine years in the brushes of Mt Royal*". (Aurousseau 1968 p630)

As he travelled north, there would have been tantalizing glimpses of the high mountains to the north; he would have followed a regularly travelled track with Fal Brook (also known as Glennies Creek) to the west and the high forested ridges of Mount Dyrring on the east. The hills narrowed near the present Lake St Clair dam wall, before the valley widened at *St Clair* homestead, where Carrow and Fal Brooks join, the sandstone and conglomerate cliffs of Baybuck Hill overlooked the valley providing a dramatic sense of entrance. The journey to St Clair was not without incident. His horse fell with Leichhardt "*violently shaken but broke fortunately no bone*". (Aurousseau 1968 p633)

St Clair station was owned by an absentee owner Thomas Steele. Captain Mayne the overseer was not at home when Leichhardt arrived, describing himself as a "*stranger slung around with collecting canisters and boxes.*" (Darragh & Fensham 2013 p137) but with his letter of introduction he was made welcome. The following day the south easterly winds continued, more than likely bringing pleasant slightly cloudy weather and he climbed Mt Dyrring [Dyrrine] to the south overlooking the valley and *St Clair*. This would have provided him with the opportunity to familiarise himself with the mountains to the north. He enjoyed a very beautiful view from the peak, writing "*You see a large number of strange mountain ranges, which I have tried in part to draw.*" Darragh & Fensham (p138) and his *Diary* includes a sketch of the mountains, mostly correctly named. (See Figures 2A, 2B and 2C).

Excursion to Mount Royal

The next day (Thursday 26 January 1843), the journey to the mountains commenced; with south easterly winds again

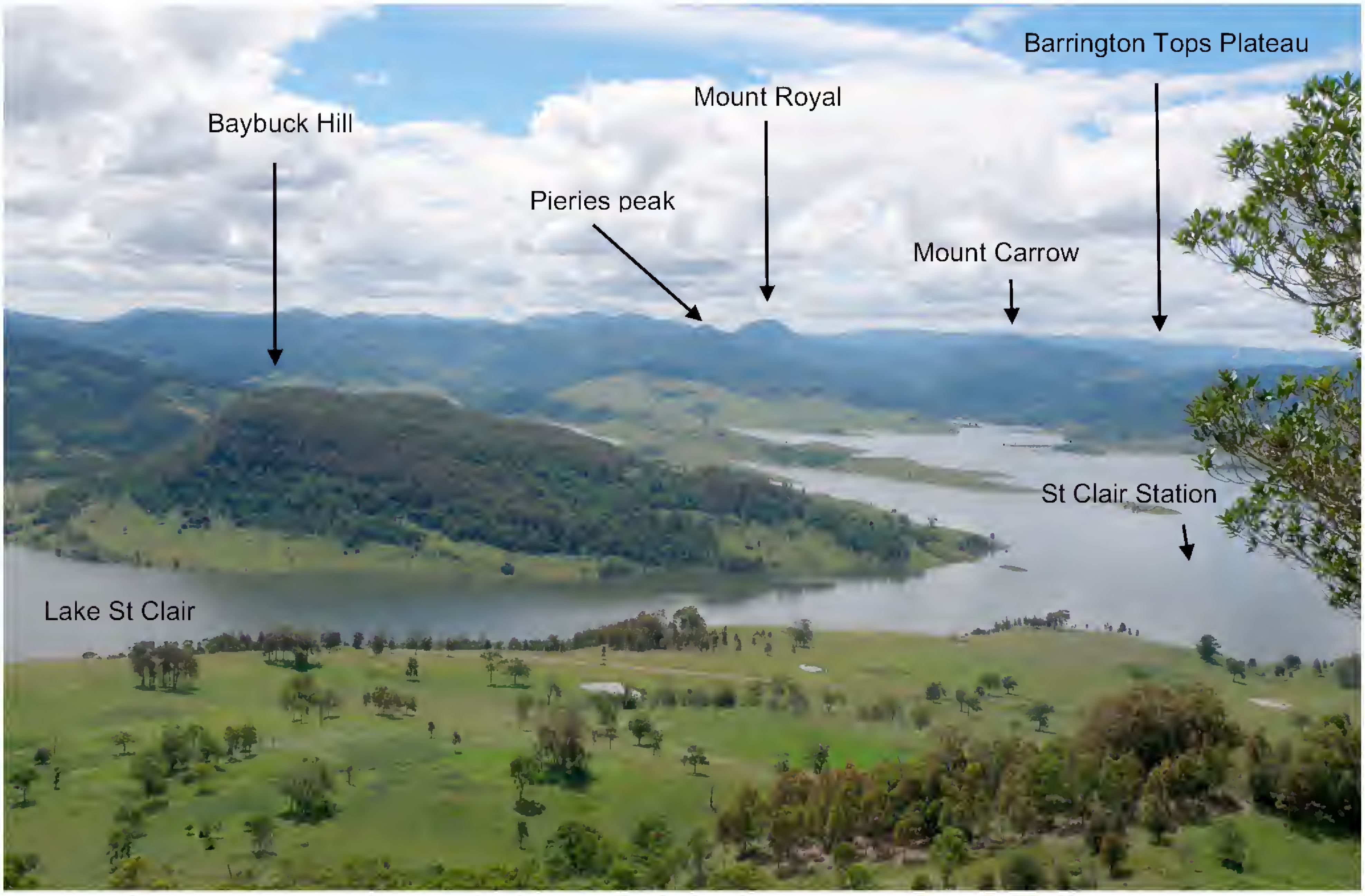


Fig. 2A. View north from northern ridge of Mt Dyrring to Baybuck and Mt Royal

blowing from the coast. The weather report from Wollombi that week noted that "*There was every appearance of rain in the early part of the week, but none has yet fallen; the verdue consequently looks sickly, and the late maize shows signs of premature forwardness.*" (Maitland Mercury, 29 January 1843) On horseback, accompanied by his dog, Leichhardt followed a track used by the sawyers to access the forests of Mt Royal. No mention is made of whether the sawyer was with him, but it is probably unlikely as Leichhardt spent much time making geological observations. The track to Mt Royal would have been quite obvious skirting east of Carrow Brook at the base of high tree covered ridges to the east and south. Leichhardt describes the grassland of the valley, which gave way to rainforests along the creek as the valley narrowed, providing a picture of the transition from open grassland country grazed by domestic animals into the forests and rainforest brushes along the creek, and the steep climb up the ridges to the foot of Pieries Peak [Piri]. "*Small*

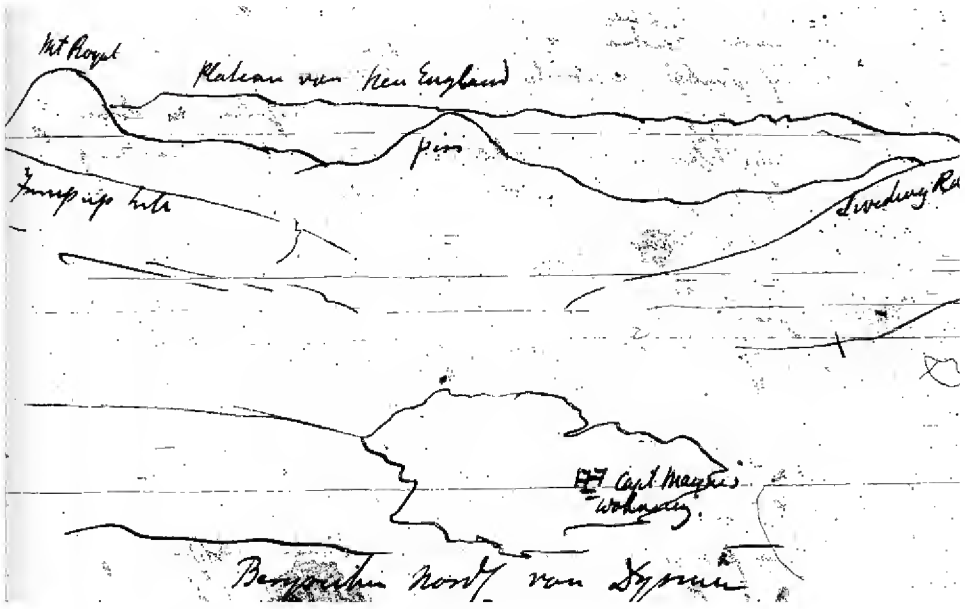


Fig. 2B. Leichhardt's sketch of mountains from Mt Dyrring (from *Diary* page 65)

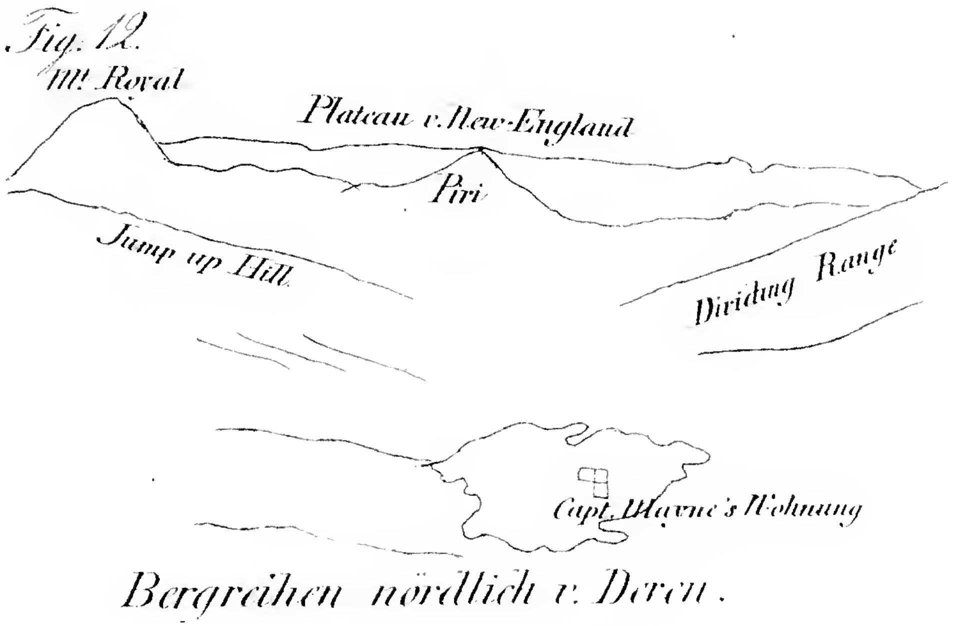


Fig. 2C. Sketch reproduced from *Diary* in Leichhardt (1855) as Figure 12

grassy paddocks in which the silvertail especially and the red feathery oats were growing. Poa was abundant too. On the stream, Casuarina gives a pleasant dense shade whilst rare ironbark, box and apple tree on the paddocks only provide moderate protection against the hot sun. Higher up, however, these paddocks discontinue after the upper ones had manifested many more ferns between the grass bushes and dense scrub (brush) formed by various rare trees took their place. Here the nettle tree with its broad ventricose leaves, heart-shaped at the base appeared for the first time, which is to be avoided so carefully because of its painful stinging." (Darragh & Fensham 2013 p140) (see Table 2 for species). Today this landscape is cleared pasture with much of the lower-lying land under the water of Lake St Clair.

Leichhardt appears to have been captivated by the rainforest along upper Carrow Brook and its tributary gullies and by the new plant species and their growth habits he was observing; "*The creepers became very numerous, the native vine stretched from trunk to trunk and made the scrub almost impenetrable. Mosses hung down in long garlands from the branches, lichens covered rocks and living and dead plants.*" (Darragh & Fensham 2013 p142) He noted fossils along the creek.

After consuming a meal of roasted Potoroo (possibly Long-nosed Potoroo – *Potorous tridactylus*) at the foot of the mountain, he followed the path which left the rainforested valley and its meandering creek, up a sledge track on which bullocks pulled cut timber down. The path to Pieries Peak [Piri] climbed for more than two miles (3.2 km) up an "*extremely steep hillock*". He noted "*We gained one terrace after the other, always sandstone covered by forest.*" (Darragh & Fensham 2013 p142)

Leichhardt refers to the distance from *St Clair* to Pieries Peak [Piri] as *14 miles* (22 km), (and about *34 miles* (54 km) from *Glendon*), and must have taken about half a day. He stopped at the base of a steep grassy ridge at the foot of Pieries Peak to camp, but not long afterwards his horse broke its bridle and ran off along the track it had come, probably taking his provisions with it. In search of his horse, Leichhardt returned to Carrow Brook valley along a ridge to Jump Up Hill, used by the sawyers and apparently named by them because of its steep northern ridge. Leichhardt refers to making the "*tiring valley and mountain path a second time*", returning to his Piri camp without finding his horse, after a round trip of about 8 miles (13 km). (Darragh & Fensham 2013 p144)

Camp at Pieries Peak [Piri]

In a grassy tall eucalypt forest almost certainly at the southern end of Pieries Peak, Leichhardt established a camp "*in a hollow black butt tree*", with the dense brush on the east of the mountain only a short distance away. The much higher peak of Mt Royal is about 3.2 km (2 miles) further north along the ridge separating Carrow Brook and Fal Brook. Occasional hollow trees similar to the one Leichhardt describes he camped in still occur in the area; a dead *Eucalyptus obliqua* tree near Pieries Peak measured 8.6 metres d.b.h. and could easily have accommodated Leichhardt's tall frame and possessions (Figure 4). The camp was probably not far from a sawyers' hut; camping at the base of the mountain allowed him to climb to the top of the mountain on a number of occasions to collect plants and contemplate nature.

In a long letter to Robert Lynd written later at *Glendon* on 19 February 1843 he wrote "*The man returned to Glendon to fetch provisions, so I lodged myself in a hollow black butt tree in which I could just extend the full length of my body. I took the long leaves of the fern tree and spread them over the floor and over the walls of my lodgings. A cheerful fire was burning before it. So I lived alone, accompanied only by my dog for four days, making excursions to the different parts of the mountain. For Breakfast, Dinner and Supper I had my tea and suggar, damper and bacon. Before sunset I ascended frequently Piri, from the top of which I enjoyed the most beautiful view over the distant mountain Ranges, which have very generally a direction from North to South. This view is not so grand as that from Mt Royal, which is above all description magnificent, laying this mountainous country like a map before your feet, with all the valleys and creeks or brooks which rise from its flancs. Fallbrook from the west, Carrocreek or Busby creek from the East, the Paterson and Allan River from the North or North East. At nightfall I descended to my hollow tree prepared my tea, wrapt myself in my blanket and watched Orion and Sirius gliding slowly through the foliage of the black butt. The flying squirrel commenced to call, the Wallabi came from the brush to browse on the rich grass of the forest and the mountains. I felt myself exceedingly happy, dreamt with open eyes, till the eyelids became heavy and the head sunk to the saddle which formed my pillow.*" (Aurousseau 1968 p633)

During his four days alone, with consistent south-easterly winds bringing partly cloudy and cool weather, he explored the ridge of Pieries Peak from south to north on foot, as well as the rainforest brushes. Herbarium specimens collected at *Mt Royal* and *Piri* are marked with dates from this period. He made many observations of plants and the landscape including sketches of the geology of the area (Figure 4). His herbarium specimens and *Diary* records show a particular interest in ferns and rainforest plants.

The weather in much of the Upper Hunter is typically much drier than at Mt Royal and the *Maitland Mercury & Hunter River General Advertiser* of Sat 11 Feb 1843 noted "*The atmosphere has been threatening for rain for some days, but none has fallen. The country from Murrurundi to Singleton is in a deplorable, parched up state, neither grass nor water; and to show the dryness of the season, Glennies Creek, that has always been full of water at the crossing place, near Johnstone's inn, has now ceased running; a circumstance the more remarkable as no person ever remembers seeing it so dry before, or void of a running stream.*" In contrast, there was still water in the springs and gullies of the mountains.

Kurranulla Creek

On 29 January Leichhardt returned to *St Clair* to track down his horse. "*I had descended Piri and after I crossed a thick scrub, in which the tree-like lianas obstructed my way, so* *that I often had to clear it myself with knife and hammer, I came to a forest ravine, which lead down from Jump Up Hill to Carro Creek.*" (Darragh & Fensham 2013 p149). On the left side of a brush*" I found a large number of plants, which it is true I had already seen in other neighbouring localities, but which I would like to have collected together, which is why on passing them I wrote down short notes about them.*" (Darragh & Fensham 2013 p147) His *Diary* includes detailed descriptions of various plants from here.

This third day alone he spent the night camped near a creek in a "ravine" flowing east from Jump Up Hill (now Kurranulla Creek). The ravine "*was filled by pudding* [conglomerate] *and sandstone blocks, and trees were either driven down the river from the mountains and were piled up by floods or the storm winds had broken them down and they now lie across the ravine. They had pulled over the lianas that climb up on them and these stretch from one bank to the other like ropes, even if the original tree is already destroyed, as the lianas striving upwards had already twined around new trees again. However, it was so late and because the ravine widened somewhat and presented a dry rocky bed free from boulders, in the bottom of which beautiful water was found, I made my fire with the wood of the nettle tree and with the dry foliage of Acmena, with which the heat had amply covered the rocks. Here I consumed my last piece of bread with a piece of bacon and a pot of tea. The night was dark, the ravine banks high, their edges crowned with tall trees, while lower growing bushes descend to the bed and cover the banks. The blazing fire moderately illuminated this forest scene. Sirius seemed to me lower. The ground cricket incessantly sounded its simple call. The flying squirrel chattered, then a gust of wind, which rustled through the crowns of the tall trees and the dry fallen foliage, through which small quadrupeds and lizards moved rustling here and there. In the morning parrots raise their incessant noise, the cockatoo sweeps screeching over the highest crowns of the trees. If I had previously regarded it as impossible to be able to live solely on fat, such as bacon, I now found, because my bread had run out, that this was very easily done, provided you take only small quantities at the beginning, so as not to suddenly overfill the stomach.*" (Darragh & Fensham 2013 p149)

Kurranulla Creek and its ravine is a Leichhardt location that can be readily recognised today. Its rocky pools and cascades flow into Carrow Brook in a sheltered rainforest with an open leafy forest floor. Upstream the creek narrows and flows through rock outcrops, a narrow band of rainforest

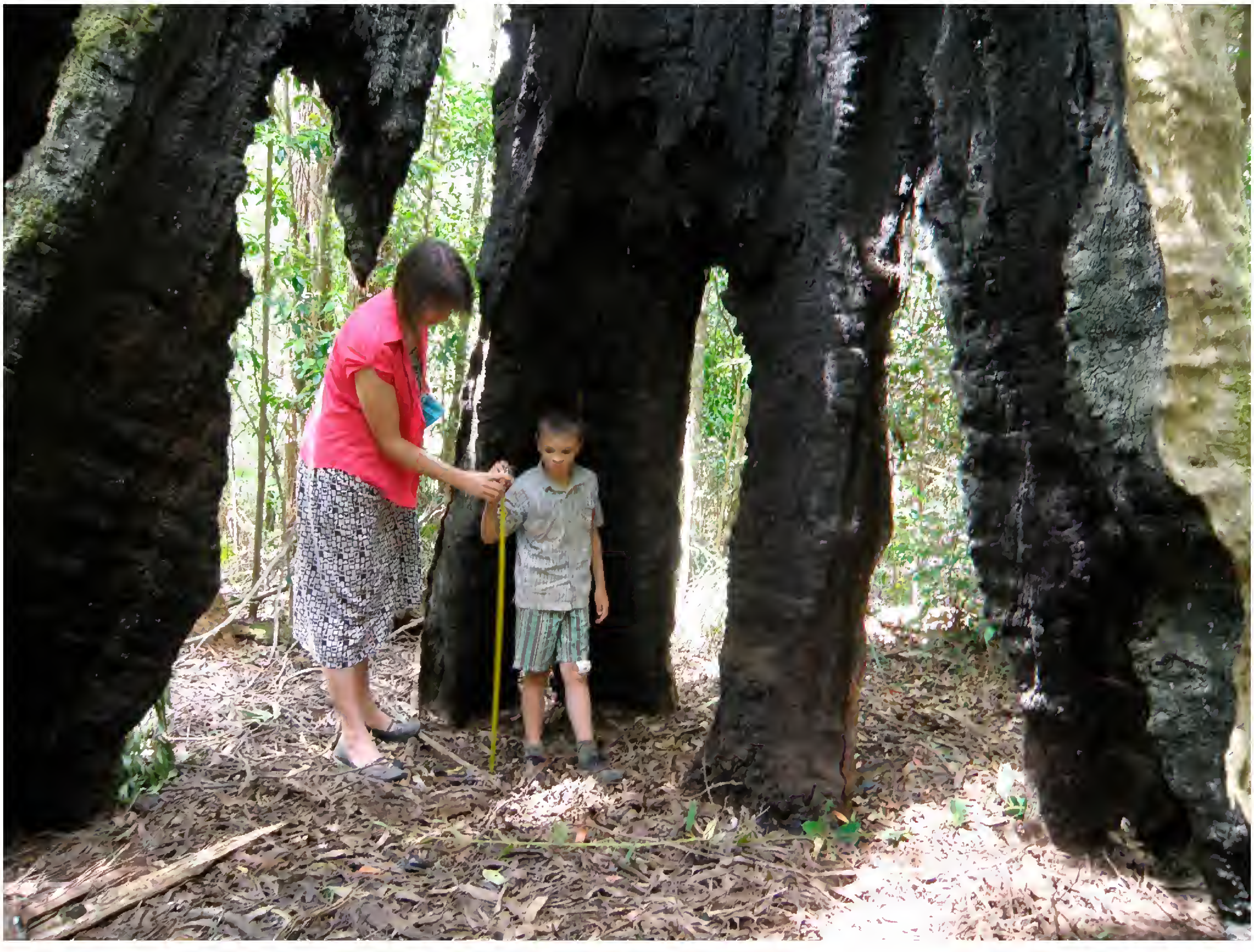


Fig. 3. Large dead hollow *Eucalyptus* tree near Pieries Peak, likely to be similar to the one Leichhardt described at his campsite in the area

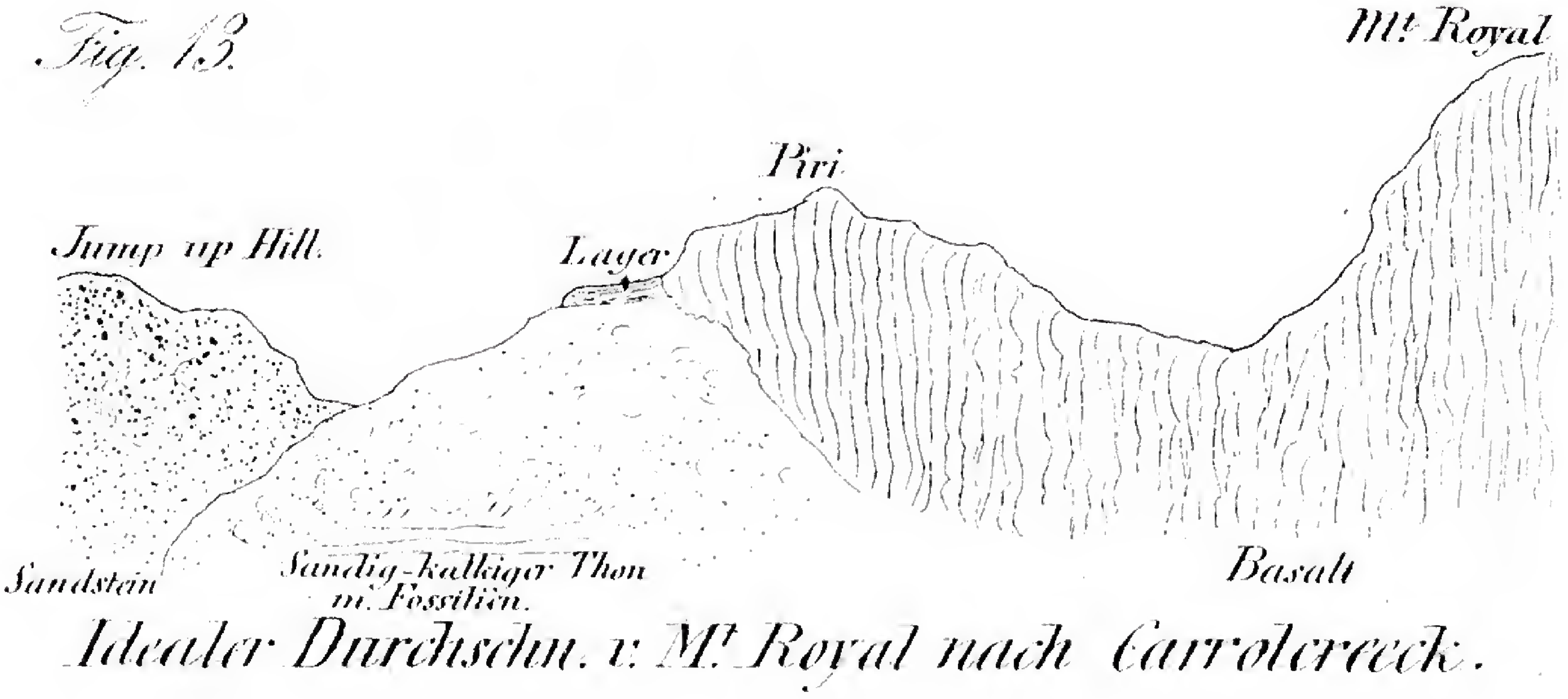


Fig. 13.
Mt Royal
Piri
Jump up Hill.
Lager
Sandstein
Sandig-kalkiger Thon m. Fossilien.
Basalt
Idealer Durchschn. v. Mt Royal nach Carrolcreek.

Fig. 4. Copy of Figure 13 from Leichhardt (1855) – Cross section from Jump up Hill to Mt Royal (note that this corresponds with *Diary* sketch 32 page 69). '*Lager*' indicates his campsite below Pieries Peak.

through the tall eucalypt forest on either side. Leichhardt's descriptions of the landscape here are still applicable now, and plant species noted by Leichhardt in this creek still occur there.

On the afternoon of Monday 30 January he walked the 10 miles back to *St Clair* to stock up on provisions and to find his horse. "*It had fought its way in some inexplicable manner to the valley and had joined Captain Mayne's mares there*". (Darragh & Fensham 2013 p153)

Return to St Clair, Mt Royal revisited

The next two days were wet and Leichhardt remained at *St Clair* writing up his *Diary*, exploring the vicinity of the homestead, and probably visiting the cliffs on Baybuck [Babock], a large and prominent hill overlooking *St Clair.* Following the return of the bullock dray from *Glendon* with provisions for him and the sawyers, he returned with his horse to his hollow tree at Pieries Peak. "*Having returned*

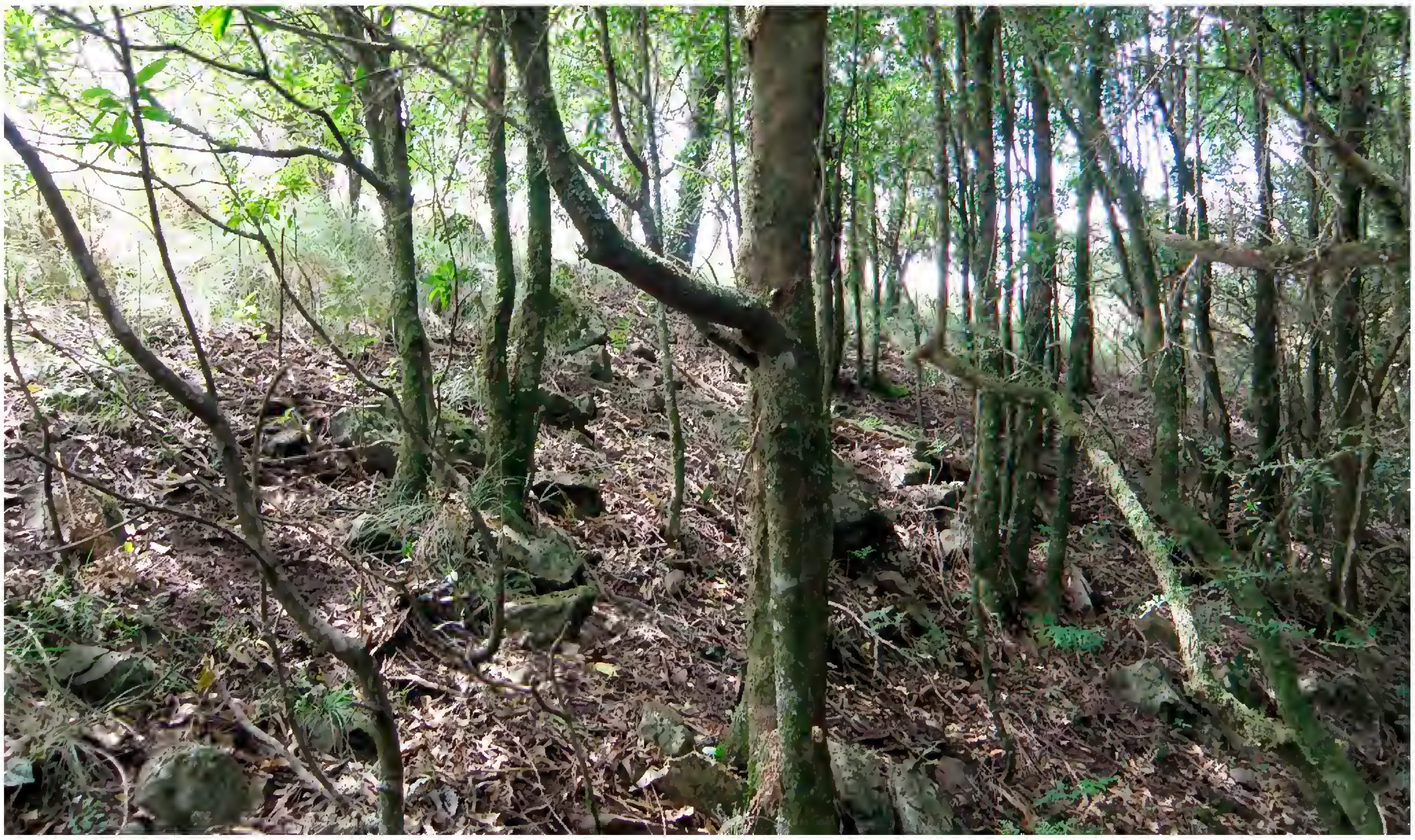


Fig. 5. Rainforest on Pieries Peak, eastern side

to Piri, I began to collect and dry my plants, but I had to struggle with a good many difficulties. The trees in the brush are extremely tall, so it is almost impossible to identify leaves, stem and fruit if you are able to get the fruit and leaves at all." (Darragh & Fensham 2013 p153).

In a letter to Robert Lynd written later from Glendon, he describes further difficulties "*Mr Scott had sent me 5 quires of paper* [folded papers for drying his pressed specimens] *to collect plants for myself and for him and I wished to study the brush with leisure. But scarcely arrived at the mountain my horse went off a second time, I had to track it for 10 miles and to ride back without saddle and bridle (which latter I had forgotten in the hurry of the pursuit). As I was drying my paper the fire crept through a hollow branch up to it and destroyed not only 2 quires but also my shirt which I had just washed. At night the wind blew rather hard and carried one of the fern trees of my lodging, which were very dry, in the fire. The fire ran along it over to the tree to my blanket and at scarcely a moments notice I was all surrounded by the flame. As I was fortunately awake, I jumped up like lightning and threw blanket and everything from me.*" (Aurousseau 1968 p634)

His *Diary* gives more details. "*During one night one of those large Alsophila* [tree fern] *leaves fell out of my tree into the fire. The fire ran along it into the tree and then the blanket and tree were on fire. Fortunately, I was awake and could protect myself from burning, by throwing everything from me and jumping out of my camp. Then only two quires of paper and a shirt were burnt and finally I lost my pencil. This probably could have discouraged a man. In addition, I had to wash, to cook, and to wait for my horse until the rain drove me into the hut of the sawyers, who took over that duty for me. However, I felt extremely happy and cheerful and now pulling rheumatic pains in the small of the back alarm me. Only the limited extent of my resources distressed me. Everywhere I felt (?) the scantiness of my resoures with the existing abundance. However, I brought down many an interesting object with me.*" (Darragh & Fensham 2013 p153)

Rain continued the following day as did Leichhardt's frustrations. "*To fill the cup of my misfortunes, I lost my pencil next day and could not put any notes down. Rain commenced, I was compelled to send my plants home half dry and in order not to loose them, I had to follow them about 4–5 days afterwards.*" he wrote to Robert Lynd (Aurousseau 1968 p634)

In the cloudy and showery weather that continued for the next few days he presumably spent more time walking and observing, while staying somewhere near Pieries Peak with the sawyers. However Leichhardt always remained positive later writing to Robert Lynd "*Is this not enough to discourage a poor soul, with no friend and comforter near him? I took it however very cheerfully, except loosing of the pencil, for I knew that I had kind friends who would say afterwards 'thank heaven that you are safe now' and so I thought with Eneas 'Et haec meminisse juvabit* [Virgil, *Aeneid.* It will be delightful to remember this one day]." (Aurousseau 1968 p634)

Leichhardt's *Diary* and letters are unclear about the length of his visit to Mt Royal, notwithstanding one of his letters describing it as about 3 weeks. He appears to have camped near Piri from 26 Jan to 30 Jan (5 days), and returned again from 2 February to 8 or10 February (6 or 8 days), about 2 weeks at Mt Royal overall, and about 20 days in the area. Appendix 2 shows Leichhardt's activities at Mt Royal in chronological order.

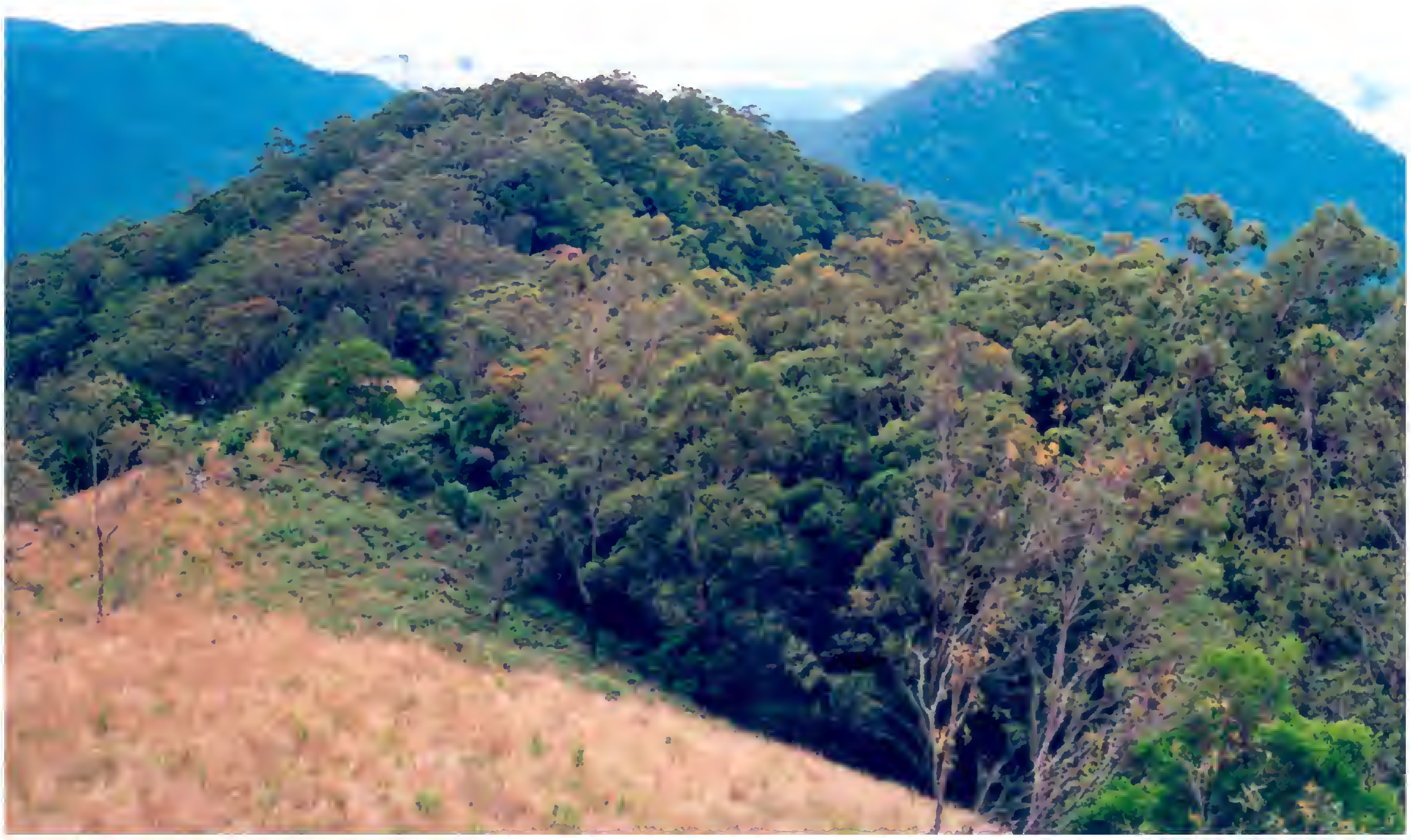


Fig. 6. Looking north to Mt Royal from Pieries Peak, showing grassland 'bald' in immediate foreground

On 20 February 1843 Leichhardt reflected on his visit to Piri. "*One evening as I went along on the highest ridge of Piri, an eagle passed over me in tranquil flight. It moved in circle upon circle around me. Finally it stopped right over me and now descended, probably to overcome me. The sun had set, but the sky was still light and clear, not a voice enlivened the stillness of the forest and mountain. I felt uneasy in the presence of this animal. I was not apprehensive, but could not bear this state of fearful suspense, so I put my stick against my cheek like a gun and puff the animal showed his fright in sudden quivering of his wings, which it immediately spread again to peacefully float further in the still air. It moved along the mountain, perhaps it was waiting for a wallaroo. Perhaps it had hunted the whole day in vain and was now very hungry. It returned again, circled around me again and finally left after a long sweep as the darkness became denser.*" (Darragh & Fensham 2013 p155)

Return to Glendon

He returned to *Glendon* around 12 February where he stayed for about three weeks, attending to his plant specimens, writing letters, and adding to his *Diary*. Leichhardt's inquiring mind and attention to detail extended to observations of the grape picking and wine making at *Glendon* that European settlement had introduced.

In his letter dated 19 February to Robert Lynd he remarked "*I shall still remain for some time in Glendon. I shall therefore expect your answer here. I am going afterwards to Dalkeith at the Liverpool Range. Mr Boydel has invited me to come to the Paterson, but I shall probably delay till I return. We have bushrangers here who have robbed several gentlemen, one of which Mr Hentig escaped very closely. The long rains have set in Friday last and they are very much required, for the grass which was so rich when I left for Mt Royal was all gone when I returned.*" (Aurousseau 1968 p635)

Weeks of wet weather and flooding followed, although it is difficult to gauge whether this was exceptional or normal summer weather at the time.

The scientific results of the Mt Royal visit – Leichhardt's plant and animal collections

An idea of the extent of Leichhardt's botanical knowledge, as well as the conditions under which he made his collections, comes through in his letters to Robert Lynd. For example "*I have found a good number of fine plants, which will increase considerably our collection. I wished I could send you all I have now. A new asplenium, a new pteris some of the Norfolk island ferns. A number of little leguminous plants, some very pretty ones. Leaves and branches and sections of wood and some fruits of the brush trees for instance the red Sterculia. A fine Orchis with a pink flower was found at the hill before Piri. Some specimens are not well dried, but the greater number is tolerable.*" (Aurousseau 1968 p634)

The wet weather and occasional accidents with fires made the process of drying specimens difficult. Leichhardt mentions changing his plant collecting methods. "*If many of my Newcastle specimens were bad, you must remember that I had to dry and to make excursions. I follow however*

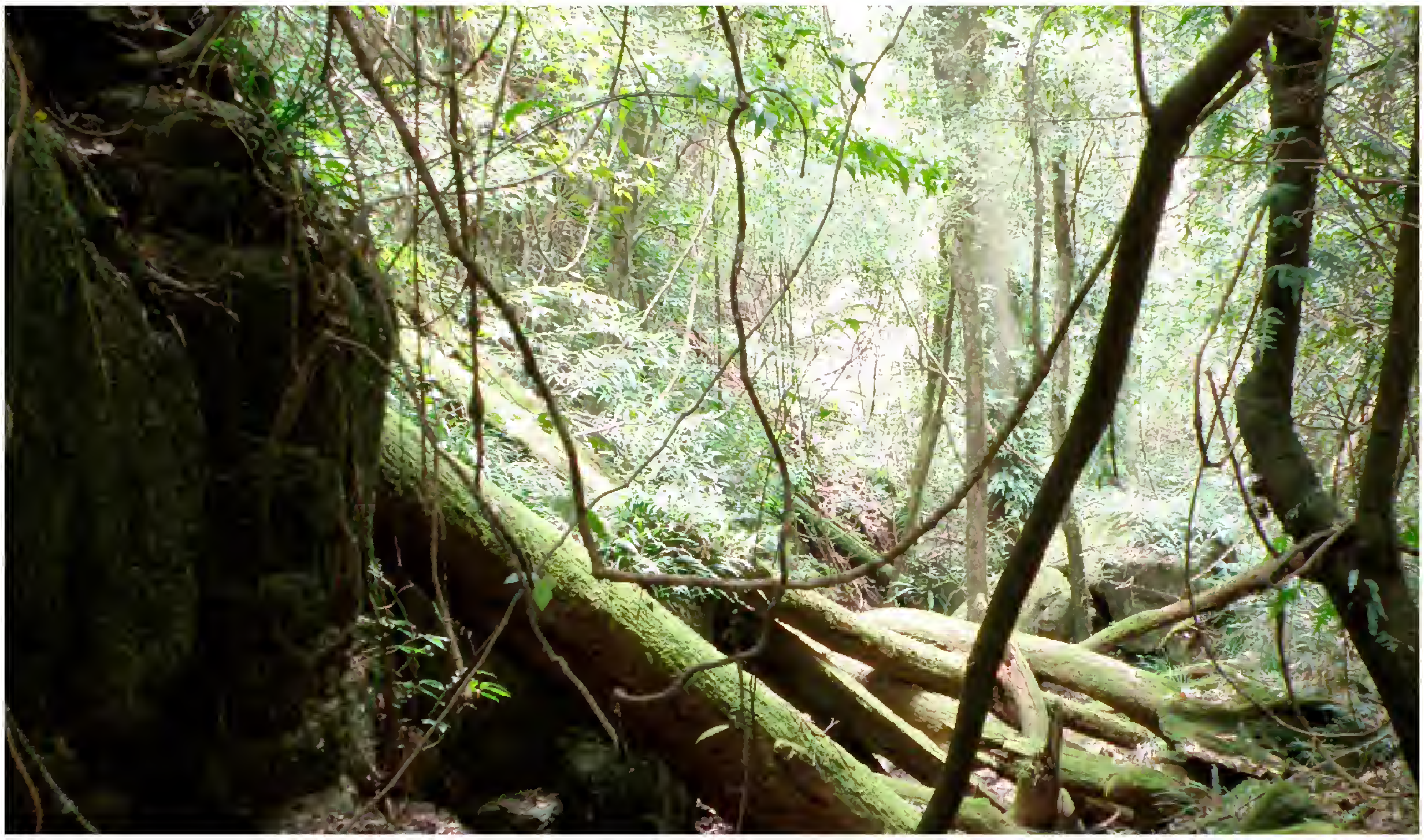


Fig. 7. Rainforest gully along Kurranulla Creek (ravine)

Table 2 Leichhardt's plant collection locations at Mount Royal, January – February 1843 with extracts from his descriptions, plant specimens he collected or noted, and notes on the current (2013) landscape.

Location, map reference ***& 1843 landscape description***	**Specimens collected by Leichhardt (source NSW or MEL) and species noted in his fieldbooks or letters**	**Current landscape (2013)**
St Clair Station (Captain Maynes) (Map ref 1) Open grassland with garden areas and pasture	*Centipeda minima – Creek of Capt. Mayne's* – MEL *Gratiola peruviana* – NSW *Geranium* sp *Ottelia ovalifolia* – NSW **Sonchus oleraceus* **Sysimbrium* sp	Now flooded by waters of Lake St Clair
Dyrinne (Map ref 2) (Mt Dyrring), endpoint of Bundock Range *"Valley of Fallbrook is bounded towards east and west by high mountain ranges. Generally of sandstone and pudding"#. "Southern walls of pudding are covered by rich vegetation, and a large number of lichens and mosses. "You see a large number of strange mountain ranges, which I have tried in part to draw."*	Dendrobium speciosum *Pyrrosia rupestris*	Steep slopes and gullies with grassy forest. Used for cattle grazing
Carro Creek (Near Map ref 3) (Carrow Brook), upstream of Captain Maynes *"Small grassy paddocks in which the silvertail especially and the red feathery oats were growing. Poa was abundant too. On the stream, Casuarina gives a pleasant dense shade whilst rare ironbark, box and appletree on the paddocks only provide moderate protection against the hot sun. Higher up, these paddocks discontinue after the upper ones had manifested many more ferns between the grass bushes and dense scrub (brush) formed by various rare trees took their place."*	*Rumex brownii – Rumex from Carro Creek* – MEL *Angophora floribunda,* *Dendrocnide excelsa,* *Poa* sp *Casuarina,* *Brachychiton populneum* *Ficus coronata* *Polyscias* sp *?Typhonium brownii or?Alocasia brisbanensis* *Pteris* sp *Asplenium* sp *Dictymia brownii,* *Cheilanthes sieberi?* *Lastreopsis or Polystichum* *?Arachniodes aristata* identification of *silvertail* and *red feathery oats* uncertain	Open grassland and scattered trees due to past clearing and rainforest in sheltered gullies. Lower slopes have been inundated by the water of Lake St Clair
Upper Carro Creek and Glennies Stockyard (South of Map ref 3) *"In these creeks and mountain brushes magnificent cedars were found. Rosewood, mahogany and bluegum are also valued by the cutters who fell trees.* *As you gradually descend to the valley and the valley floor widens, small grassy flats occur, here mostly covered with the silvertail, purple pinnate oats and a fine-leaved Poa. The various species of Eucalyptus occur in place of the brush plants, ironbark, stringybark, and spotted gum."*	*Scleranthus* sp – *Piri, Head of Carro Creek, the Hunter* – MEL *Pimelea ligustrina – Pimelia brush of Piri and Carrow Creek, r(t)ough bark* MEL *Senecio bipinnatisectus – Carro creek* – MEL *Senecio bipinnatisectus* – NSW *Toona ciliata* *Angophora floribunda* *Casuarina cunninghamii* *Persicaria* sp	Open grassland and pasture with scattered trees. Some lower flats used for cultivation. Generally grazed.

Location, map reference **& *1843 landscape description***	**Specimens collected by Leichhardt (source NSW or MEL) and species noted in his fieldbooks or letters**	**Current landscape (2013)**
Piri (Pieries Peak) (Map ref 4) **Piri forest** The west side of the mountain is treeless *"covered with the most beautiful grass"*.	*Acacia filicifolia – The wattle from Piri forest*–MEL *Cheilanthes tenuifolia – Top of Piri*–MEL *Cyathea australis* *Desmodium brachypodum –top of Piri Jan 43* – NSW *Eucalyptus viminalis – Gums from piri forest Jan 43* – NSW [Note this is probably E. nobilis) *Fimbristylis dichotoma – Top of Piri* – MEL *Juncus continuous – Grasses from Piri* – MEL *Opismenus hirtellus – Grass from the Top of Piri* – MEL *Platysace lanceolata – Trachymone Piri Forest* – MEL *Pteridium esculentum – Pteris aquilina* *Sambucus australiasica – Native Elder, Forest of Piri*–MEL *Senecio linearifolius* var. *arachnoideus – fennel scented Senecio, forest of Piri Jan 43)* – NSW	Steep slopes with tall grassy forest and rainforest on eastern slopes. Western slopes of Pieries Peak are treeless grassland. Within Mt Royal National Park.
Piri brush (rainforest) Thick rainforest canopy, predominantly on eastern slopes. *"The easterly slopes of both mountains are covered with thick brush, in which the red cedar, a noble tree of 90 to 100 feet and more, the nettle tree with its broad, stinging leaves, and the tree fern are found – and they're all bound together by climbing plants and lianas, and covered with creeping and parasitic plants, and mosses and lichens."*	*Acaena agnipila* – MEL *Astrotricha tatifolia* – MEL *Blechnum patersonii* subsp. *patersonii – piri brush Jan 1843* – NSW *Brachychiton acerifolius – Red Sterculia leaves and red flowers Brush of Piri* – MEL *Caldcluvia paniculosa* – MEL *Cryptocarya glaucescens* – MEL *Cryptocarya obovata – Piri Brush … tree?* – MEL *Callicoma. Small tree^* – NSW *Orites excelsa – Small tree in the brush of Piri* – MEL *Dendrobium pugioniforme brush of Piri – NSW* *Diploglottis cunninghamii – leaf of a tree from Piri brush Jan 43* – NSW *Doryphora sassafras – Sassafras tree in the brush of Piri* – MEL *Dysoxylum sp – Red Cedar leaf from Piri brush* – MEL *Elaeocarpus kirtonii – Brush of Piri* – MEL *Elatostema reticulatum – Dorstenia from brush of Piri* – MEL *Elatostema reticulatum – Dorstenia? from piri brush Jan 43*) – NSW *Emmenosperma alphitonoides* – MEL *Ficus coronata – Native fig from the brush of Piri* – MEL *Lomandra spicata – Xerotes from Piri brush* – MEL *Rubus nebulosus – Piri Brush a vine* – MEL *Urtica incisa – Nettle of Piri brush* – MEL *Vesselowskya rubifolia – piri brush Jan 1843 together with Dorstenia grateola*	Sub tropical to warm temperate rainforest on the eastern side of Pieries Peak and in incised gullies.
Jump Up Hill (unnamed but northern ridge is called Jump Spur) (Map ref 5) Jump Up Hill consists of sandstone, and is given its name *on account of its steep northern slope.*	*Dipodium punctatum*	Tall Eucalypt forest and grassy understorey. Previously heavily logged and partly cleared in private ownership.
Forest ravine (Kurranulla Creek) (Map ref 6) Thick gully rainforest "*in which the tree–like lianas obstructed my way, so that I often had to clear it myself with a knife and hammer, I came to a forest ravine, which lead down from Jump Up Hill to Carro Creek."* *" The ravine widened somewhat and presented a dry rocky bed free from boulders, in the bottom of which beautiful water was found."*	*Acmena smithii* *Dendrocnide excelsa Nettle tree,* *Dictymia brownii – Polypodium attached to trees and rocks in the brushes of Piri, Mt Royal, Carrocreek Jan 29, 1843* – NSW *Doryphora sassafras Sassafras,* *Hedycarya angustifolia* – NSW *Marsdenia rostrata* *Orites excelsus* – NSW *Polyosma cunninghamii* – NSW *Sambucus australasica* – NSW Identification of *Ricinus, Rosewood, and cohiti wood* uncertain	Steeply incised rocky rainforest gully in tall Eucalypt forest with grassy understorey. Within Mt Royal National Park,with past logging activity.

Location, map reference ***& 1843 landscape description***	**Specimens collected by Leichhardt (source NSW or MEL) and species noted in his fieldbooks or letters**	**Current landscape (2013)**
Mt Royal (Map ref 7) *The most magnificent view on the peak of Mt Royal repays all the effort of ascending. Mountain ranges, sharp ridged summits. The course of the waters is so surveyable and clear. It is a sea of hills and ridges, which vanish in the blue of the horizon. The Fallbrook and Carro Creek come from the rich brushes of the flanks (at least of the latter). A sharp ridge richly strewn with basalt rocks, which contain olivine, ilmenite and aragonite. Also at two thirds of the height a tendency to prism formation is found, but they are more irregular slabs. Also here, as on Piri, the eastern side is densely covered with rich scrub, whereas the western appears partly bare. The ridge becomes so sharp at the end that you have to clamber up over a wall of large granite blocks.* *Whilst the lower part of the mountain is probably formed from massive basalt rocks, covered by a thin soil, the peak itself is formed from separated pieces of prisms often very regular, but heaped higgledy piggeldy over one another, between which much moisture is retained, which permits great assistance to the plant and tree life. So this rock wilderness is covered with a dense forest of bushes, undergrowth and low trees, between which the beautiful plants proliferate and especially large numbers of ferns. …Arborescent climbing plants creep up on the trees and Polypodium and species of orchids with aerial roots cover the trunks. Long moss and lichen bundles hang down from the branches.*	*Senecio bipinnatisecus* – MEL *Lomandra longifolia labill.* subsp *longifolia* – MEL *Carex dechinata* – MEL *Lepidosperma leterale?* – MEL *Notodanthonia longifolia* – MEL *Sorghum leiocleolum?* – MEL *Rubus rosifolius* – MEL *Acaena novae-zelandiae* – MEL *Rubus parvifolius* – MEL *Acacia maideni – At the top of Mount Royal* – MEL *Australopyrum pectinatum* – MEL *Senecio hispidulus – pinnatifid senecio* *Mt Royal* – NSW *Pellaea nana* poss LL *Mount Royal* *Dictymia brownii* – NSW *Echinopogon ovatus – Mount Royal; Glendon* – NSW *Cheilanthes sieberi* Kunze subsp. *sieberi* – NSW *Themeda australis* *Cyathea australis* or *leichhardtiana* *Acacia melanoxylon* *Hakea eriantha* *? Notelaea longifolia* or *venosa* *Astrotricha* *?Cassinia compacta* *Pellaea falcata* var *nana* *Viola* sp *Geranium* sp *Desmodium brachypodum* *?Lobelia serrata* *?Epilobium undulatum*	Steep rocky slopes with dense forest. Tall grassy forest on western slopes and rainforest on south east. Some patches of treeless grassland near mountain top. Within Mt Royal National Park.
Babock (Baybuck Hill) (Map ref 8) *The mountain with almost vertical southern rock walls*	*Cissus opaca – Vine from the south cliffs of Bebock Capt. Mayne's* – MEL *Cayratia clematidea – Vine from the south cliffs of Bebock Capt. Mayne's* – MEL *Clematicissus opaca – a vine from the southern cliffs of Bibock near Capt Maynes Jan 29 1843*–NSW *Dendrobium pugioniforme* – NSW *?Platylobium, Bursaria, Correa reflexa, Dendrobium speciosum, Pyrrosia rupestris, Scaevola albida, Baeckea, Dendrobium speciosum, Pyrrosia rupestris, Kennedia rubicunda, Cheilanthes, Adiantum hispidulum, Adiantum formosum, Lomandra, Commelina cyanea*	Steep, rocky slopes with cliffs. Grazed grassland with scattered trees and areas of grassy forest, and rainforest species in sheltered locations

Notes:

Spelling of locations is as used by LL. In some cases his spelling is inconsistent and the most common usage is used. See Table 1 for comparison of current and past place names

Current taxonomic names are used. Some additional species are noted in the *Diary* but cannot be interpreted in terms of current descriptions

Leichhardt's plant specimens are held at the National Herbarium of NSW (denoted NSW) or National Herbarium of Victoria (denoted MEL).

*indicates exotic species

# Pudding is an old geological term referring to a type of conglomerate rock

^ Leichhardt's *Diary* identifies species common to Piri brush and the forest ravine so the locations of these species may be interchangeable *now a quite different plan – whenever time permits, I get my plants dry in 2–3 days, being all the time occupied with it. The collection of small specimens which you make is just the thing we want. It is very strange, that I did never find any of the Ophioglossumes an[d] Botrychin [..] The Gleichenias are quite wanting here about. [From margin: The description of the Mimosa which you* [Robert Lynd] *sent me, agrees exactly with the little plant here. I have it in fruit and blossom. It is very abundant. This district belongs perhaps to the flora of Pt Jackson.]*" (Aurousseau 1968 p635)

The surviving specimens provide evidence of his collecting procedures. Some of the specimens still have small paper labels attached with locations in Leichhardt's handwriting e.g. *gums from Piri forest* on a *Eucalyptus viminalis* specimen or *leaf of a tree from Piri brush Jan 43* on a *Diploglottis cunninghamii* specimen. These labels are written in ink and were presumably added when he worked over his material at *Glendon* or *St Clair*. In the field he used a pencil for recording. Examples of specimens from the Sydney Herbarium are shown in Figures 8–10.

About 108 plant species at Mt Royal can be linked to current botanical terminology through Leichhardt's writings and surviving herbarium collections including 22 Mt Royal area specimens in the National Herbarium of NSW, 17 of which we sighted and photographed. The National Herbarium of Victoria (MEL) holds 40 specimens of Leichhardt's Mt Royal journey with six species common to the two herbaria. We have tabulated Leichhardt's plant collections from the Mount Royal area, his landscape descriptions, and the plant species he noted, together with a brief description of the current 2013 landscape (Table 2 Figures 5,6,7,11).

Although not primarily interested in documenting native fauna, Leichhardt referred to the native animals that he observed and their characteristics, including their culinary qualities. The species he noted (see Appendix 3) all still occur in the area today.

Comparisons with the contemporary landscape

Leichhardt's work at Mt Royal makes the area one of relatively few locations in Australia with comprehensive scientific documentation of plants and vegetation from the early nineteenth century. Yet despite these early records the first serious ecological work in the region was almost 100 years later in the classic ecological studies of the Barrington Tops approximately 20 km to the north east by Fraser & Vickery (1937a,b, 1938,1939); there is no mention of any of Leichhardt's collections by Fraser & Vickery although many species occur in both locations and vegetation descriptions are similar, as herbarium records were not available until specimens were databased after 2000.

Comparing Leichhardt's descriptions and specimens in the Mt Royal area with the same sites today provides historical evidence of the longevity of some of the major landscape and vegetation features existing today. Despite a history of logging and clearing as shown in Figure 1, substantial areas have remained relatively undisturbed and are now protected as National Park. Grassy mountain tops lacking trees and known as "grassy balds" are a feature of Mt Royal and Pieries Peak (Figures 6,11) and a small number of other peaks. The historical documentation suggests that these balds have changed little since first European settlement. Survey work in 1831 for Thomas Mitchell's map of 1834 described the summit of Mount Royal as being "*alternately brushed and clear on summit*" (Andrews 1992). Leichhardt's descriptions of Mt Royal in 1843 as covered with brush as well as patches of grassland confirms the earlier report as well as providing information on some of the plant species there at that time. The grassy balds at Pieries Peak noted by Leichhardt were later drawn on the 1883 portion plan, and show up on the earliest available aerial photography from 1939. These grassland mountain tops were identified as a notable botanical feature in Kinhill (1992).

Leichhardt's descriptions of the grassland of the valley at lower elevations (e.g. 'Carro Creek' entry in Table 2), seems to indicate that a more-or-less abrupt conjunction of rainforest with a grassy community (with only scattered hardwood trees) also occurred at valley floor altitude (and given the early date it may be inferrable that this was not simply a result of European clearing or grazing, although it might still be anthropogenic in a possible context of aboriginal burning). Unfortunately the valley floors are now denuded and altered by grazing, soil eutrophication and exotic pasture species that there are probably no remnants of such a conjunction of communities left.

That some minor landscape features observed by Leichhardt still exist today, is demonstrated by the existence of hollow trees similar to the one that provided his campsite (Figure 4). However even by Leichhardt's time European impacts were evident. Grazing by domestic stock appears to have been widespread on the lowland grassy areas perhaps for 20–30 years and Leichhardt notes some exotic plant species at least near areas of habitation. The incursions of the sawyers took them well up into the forests presumably targeting the valuable Red Cedar (*Toona ciliata*) but also cutting other species including Blue Gum. Leichhardt travelled with one sawyer who "*worked for nine years in the Mount Royal brushes and there was no brush between the Hawkesbury and Port Stephens and the Liverpool Range that he did not know*". (Darragh & Fensham 2013 p150)

As a State Forest for many years Mt Royal has had a history of logging, but vegetation surveys of the Mt Royal area carried out for forestry purposes (Forestry Commission of NSW 1988; Shields, York & Binns 1991) indicate the plant species Leichhardt observed still occur in the forests of Mt Royal National Park. Vegetation and species at some of Leichhardt's specific sites such as Pieries Peak and Kurranulla Creek (Table 2) indicate that there has been little major floristic change since Leichhardt's visit, though in contrast the landscape around St Clair has been completely inundated by the water of Lake St Clair and altered by grazing.

Finally the eagle Leichhardt watched on Pieries Peak was scared off by an imitation of shooting suggesting that firearms were already impacting the native fauna.

Leichhardt's legacy and the fate of his plant specimens

The Mt Royal journey shows the 29 year old Leichhardt as a young collector early in his career. The characteristics shown became evident in his later journeys, including a quest for knowledge, attention to detail and accurate documentation, and persistence in the face of adversity. We have been surprised by the amount of detail he compiled for the relatively short Mt Royal section of his journey from Newcastle to Brisbane, and how much has survived in letters, the recently transcribed and translated Leichhardt diaries originally written in French, English and German in old script (Darragh & Fensham 2013), and the high number of surviving plant specimens and their collection location details. The study of sections of the rest of this journey have potential to provide further insights into the natural history, especially of vegetation and plants in the early nineteenth century.

The subsequent history of the plant specimens collected by Leichhardt is not clear. His letters indicate he was sending them to Robert Lynd, and also to Scott. Some specimens were sent to Paris and Berlin (Tom Darragh to MPF pers com). According to Fensham *et al.* (2006) some of the surviving specimens from the Port Essington expedition in 1844 (many specimens had to be abandoned) were sent to Leichhardt's friend and botanical agent Gaetano Durando in Paris, and that Leichhardt requested that a set of duplicates be sent back to him in Australia. Fensham *et al.* suggest that this happened as some specimens are now held in herbaria in Sydney (NSW) and Melbourne (MEL).

Stephens (2007) indicates that after Lynd's departure from Sydney in late 1847, at least some of Leichhardt's rock and plant collections and fieldbooks were left for safekeeping with his landlord John Murphy (father of a member of Leichhardt's Port Essington expedition). After Leichhardt failed to return Murphy passed everything (including *boxes containing specimens of natural history, books etc*) over to the Australian Museum in 1853. Ferdinand von Mueller, colonial botanist in Melbourne asked to look at the plants early in the 1860s (Stephens 2007) and specimens were sent to him; it is not clear whether on loan or as a gift, but the National Herbarium of Victoria in Melbourne now holds over 2000 Leichhardt specimens. Some of these were evidently seen by George Bentham, and have presumably travelled to London and back.

In 1902 some Leichhardt plant specimens were discovered in the Australian Museum and these were transferred to the Herbarium at the Sydney Botanic Gardens (now the National Herbarium of NSW) (Stephens 2007). It is clear from the NSW Herbarium specimens that we have seen from Mount Royal, that some have been seen by von Mueller (his herbarium labels are attached (see Figure 9)), but others bear no such documentation and as there is not much duplication between the Mt Royal specimens held in Sydney and Melbourne (Table 2, Appendix 1), and may have come directly from the Australian Museum in 1902.

National Herbarium of NSW records (EMU) in Sydney indicate that of about 1000 Leichhardt specimens held there, at least 360 were collected in NSW (with about 100 from the Sydney area – including *Symphionema paludosum* his earliest surviving Australian collection), and the remainder, about 250, from the relatively little-known Newcastle to Brisbane journey. Of these 23 are from the Mt Royal area, and a further 20 from *Glendon.* Some specimens have no locality or dates but are consistent with these locations. Over 2000 specimens are held in Melbourne (MEL), including 1200 collected in NSW clearly from the same collecting trip. Of these 40 are from the Mt Royal excursion.

Dowe (2005) reviewed Leichhardt's collections from herbaria in Melbourne, Sydney, Berlin, British Museum, Edinburgh, Hobart, Kew, and Paris. He noted "*The contribution made by Leichhardt toward the development of botany in Australia is acknowledged in a number of ways. Mueller, Bentham and others noted over 500 Leichhardt collections in works, about 2800 specimens have been located in herbaria, and at least 78 specimens have been designated as types. In relative terms this is a high proportion of types to numbers collected.*" One type specimen (*Emmenosperma alphitonioides*) was collected by Leichhardt from Piri Creek during the Mt Royal visit although the specimen has not been seen by us.

Overall we have been surprised to find that as many as 3500 of Leichhardt specimens survive in Australia (including about 1200 collected in NSW and 1500 in Queensland (and about 36 from Port Essington) as well as earlier collections he made in France and Italy (Table 3). Collections from other places are likely to have been sent to him by correspondents. The majority of his collections from NSW or south-east Queensland, probably represent the greater part of his collecting output from 1843–44, and while this paper concentrates on only a fragment of that collection, we hope it will generate interest in Leichhardt's work in NSW. To assist future research and in recognition of their historical value it is suggested that specimens at the National Herbarium of NSW might be put together as a special Leichhardt collection, like the Banks and Solander collection. At present the specimens are scattered throughout the main herbarium collection.

Geology and landscape observations

Leichhardt showed a keen interest in geology; Branagan (2012) notes his "*fine geological background from two years of studying with the best French geologists*" and his *Diary* includes landscape sketches and geological diagrams of Mt Royal (Figure 4). An overview of its geology was posthumously published in German in his *Contributions to the Geology of Australia* (Leichhardt 1855) though this publication appears to have been generally overlooked.

"On the way from Glendon to Mount Royal, a southerly extension of the Liverpool Range, which at its southern end appears as a cut off cone, one first goes through a large area of hills and ranges where one never sees distant views or an overview because it is consistently covered by forest. On several occasions porphyry breaks through the sandstones and even draws the attention of the general observer through the loose heaped sharp rocks. The Fallbrook valley is surrounded by higher mountains, and the conglomerate

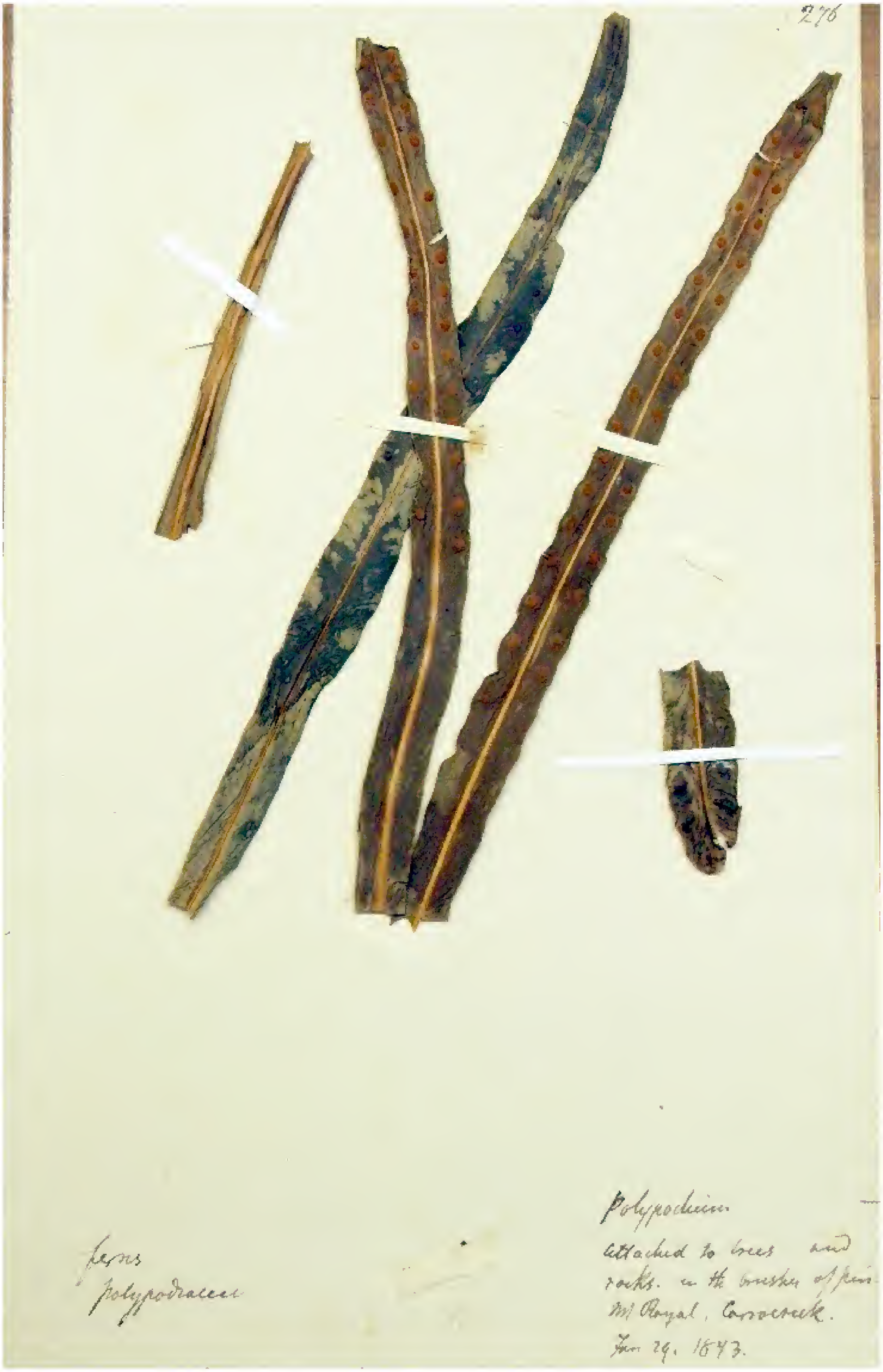
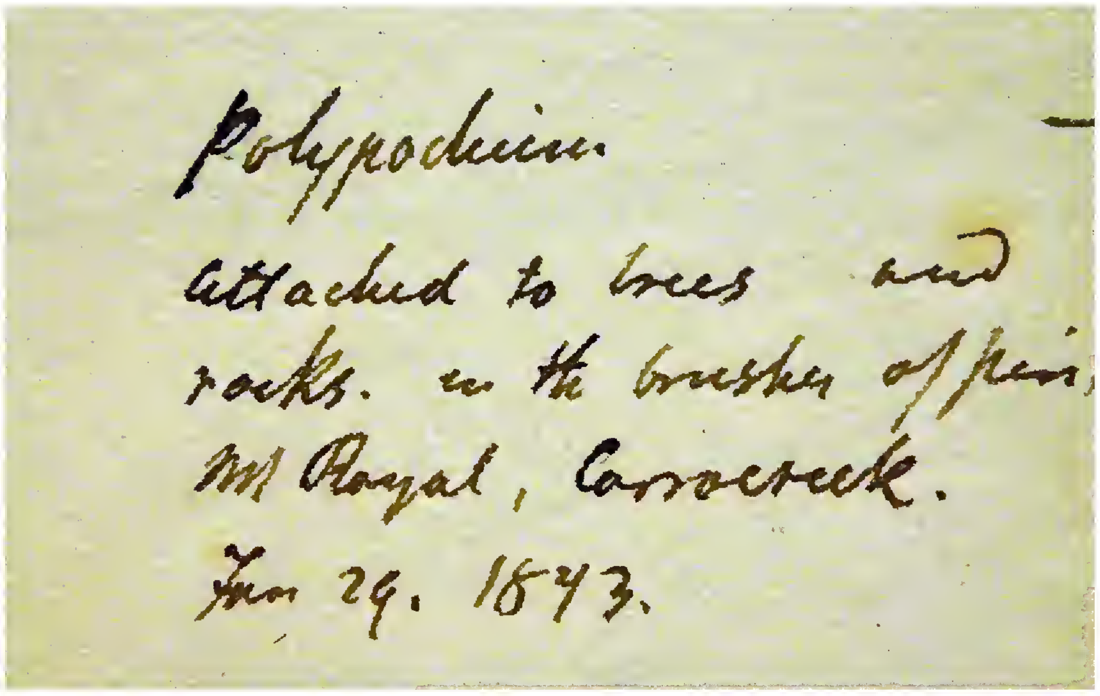


Fig. 8. Photographs of herbarium specimen of *Dictymia brownii* from Mt Royal, collected by Leichhardt.



Polypodium —
attached to trees and
rocks. in the brushes of [illegible]
Mt Royal, Carrocreek.
Jan 29. 1843.

Fig. 9. Note in Leichhardt's handwriting

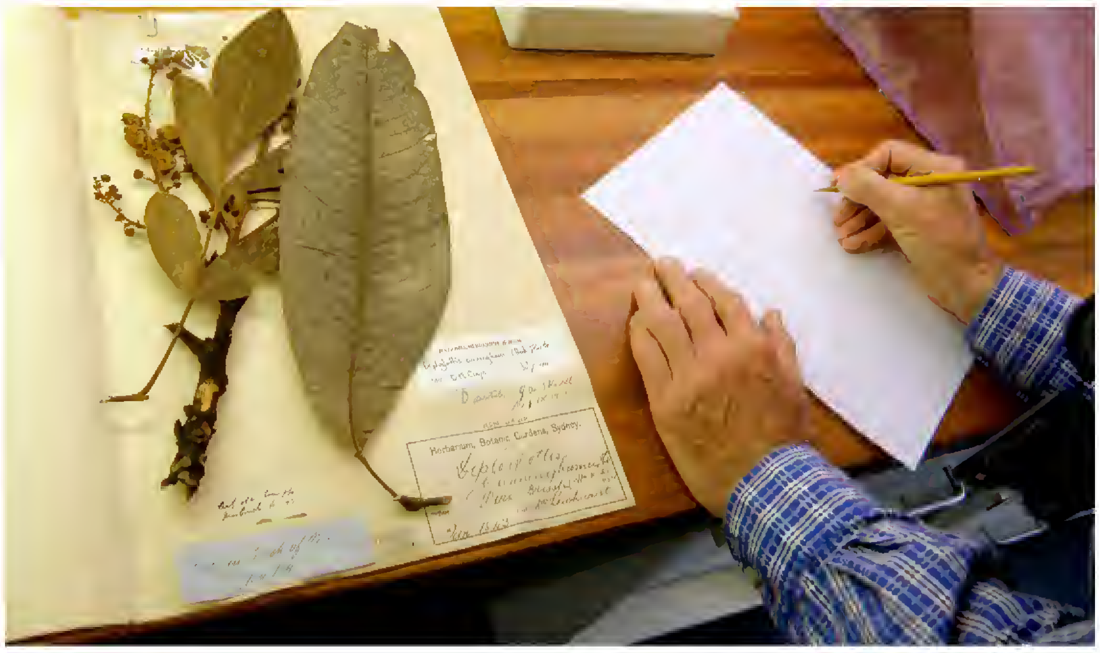


Fig. 10. Photographs of herbarium specimen of *Diploglottis cunninghamii* from Mt Royal

Table 3 Numbers of Leichhardt specimens by collecting locality held at the National Herbarium of NSW (NSW) and National Herbarium of Victoria (MEL).

According to T. Darragh (pers comm.) Leichhardt sent a significant number of specimens to Berlin (most were destroyed in a fire at the Berlin Herbarium during World War 2 except for a few ferns). There are a few specimens at Kew Garden in London probably sent by Mueller and 13 specimens at Brisbane, probably sent by Mueller, and possibly some at *Das Naturhistorisches* museum in Vienna (J Pattison pers comm.).

Leichhardt's collection areas	Sydney Herbarium (NSW)	Melbourne Herb (MEL)	total
NSW	366	896	1262
Qld	374	1264	1638
Northern Terr. (Port Essington)	11	25	36
Vict	4		4
South Aust	2		2
Tasmania	9		9
West Aust	6		6
Unknown locality but probably Aust.	284	302	586
France	10		10
Italy	9		9
New Zealand	2		2
total	1077	2487	3564

occurs everywhere. Mr Glennie has found coal at Fallbrook – between Mr Bundocks and Captain Maynes (St Clare) the syenite from Meranni is exposed several times, one can particularly observe this at the junction of two streams a short distance from Captain Mayne's. The floor of the valley and the low hills, on one of which the dwellings are built, are all composed of red conglomerate, while the higher mountains, Babock and Deren (Dyrring), comprise sandstone and conglomerate. Meranni (Mirannie) shows very similar characteristics. The same syenite can be found at the bottom of the mountain; higher up through the influence of heated rocks, is found conglomerate consisting of pebbles. Then there is a change not only in the sandstone and the syenite, but also a porphyry appears to have broken through these rocks. The summit is comprised of pudding which forms a low, vertical wall below the summit.

About 4 miles from St Clare upwards appear layers of a sandy and clayey limestone full of large (encrinite? fossil) stems, the largest 9 inches in size with a diameter of 1 inch, some of which are pressed together. The sandstone rocks lying on the grass show that this (encrinite) limestone lies directly under the sandstone.

This limestone occurs at Glennie's Stockyard and at the entrance of Carro Creek under Jump Up Hill where a fossil rich rock is exposed, which in its higher parts appears to look similar to slate. It is a sandy, lime comprising claystone. One does not notice any mica platelets. Towards the top, one sees a lot of layers: often rhomboidal and jagged, these minerals being covered and penetrated by iron and pressed into rock. – About 150 feet higher the well known sandstone is observed again and comprises the long ridge which the hunters describe as Jump Up Hill because of its steep northern slope. As well as encrinites, one finds terebratulas, bivalves and univalves in these rocks. Also some plant materials were found. Here I believe I saw a trilobite. Although I could not find this small fossil again, so I would like to make later observers aware of this location. In general, the beds dip at 13 degrees to the east.

As one climbs up to the foot of Piri over several higher terraces (See Figs 11, 12, 13) [Figure 2C and Figure 4] *are all comprised of sandstone, one notices the vigorous vegetation, the rich black soil, and the dark brown rocks, and that at last one has left the sandstone and is standing on a different formation, which one recognises as a hard, dark brown basalt with zeolite, peridot and titanium iron. This rock forms Piri, a long narrow undulating ridge, which lifts out of the sandstone like a thick wall. It goes from south to north and is connected to Mount Royal through a ridge with a few gaps that continues in the same direction, but which is significantly higher than Piri. Mount Royal as already described above, is connected to the Liverpool Range.*

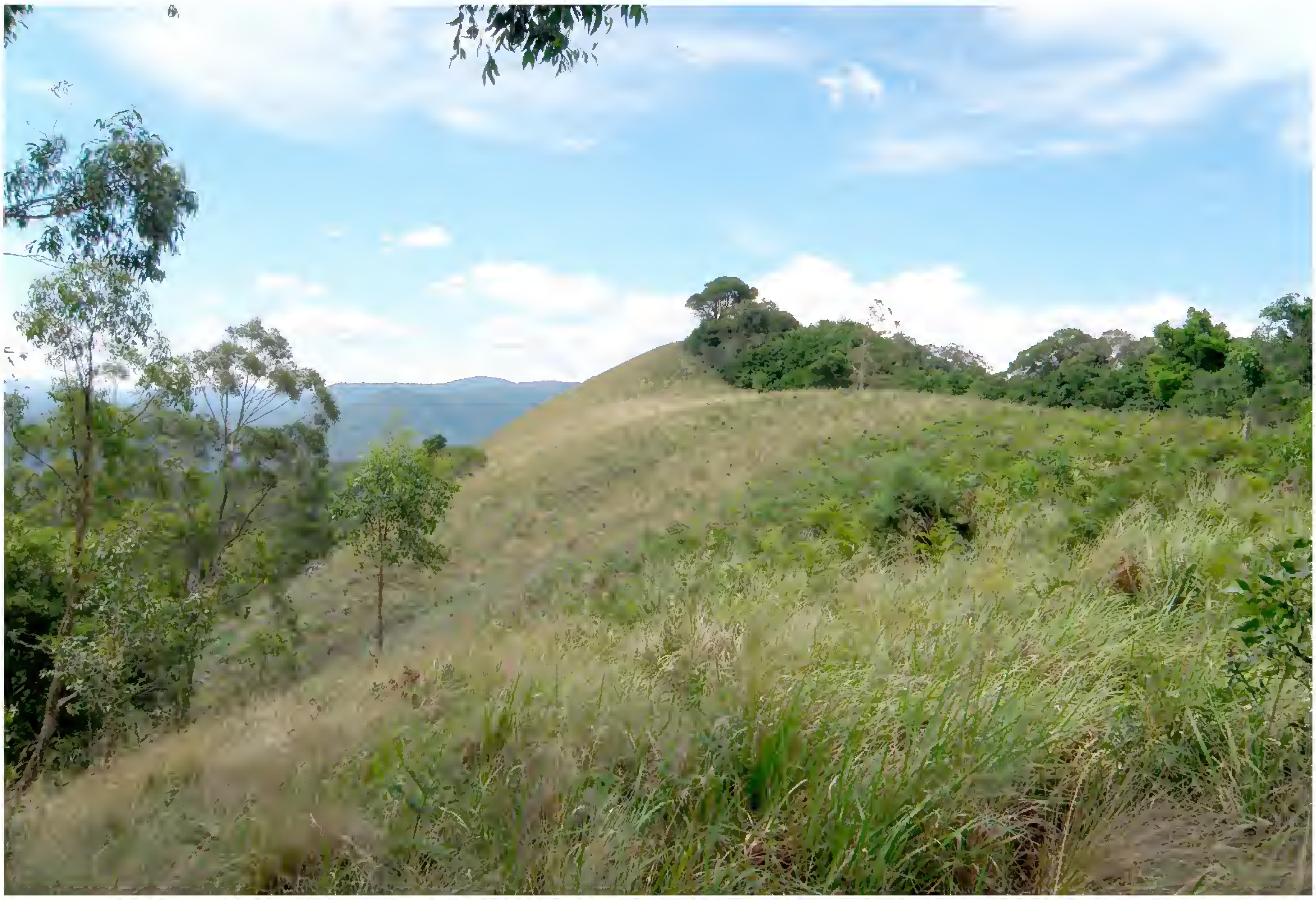


Fig. 11. Grassy bald on southern end of Pieries Peak near camp

In a few locations, the highest ridge of Piri and the wider hilltop crest (ridge) of Mount Royal are so narrow that one has to climb these as if on a wall. On these, the rocks have a tendency to form columns. The columns are rather irregular blocks. While the lower part of the mountain is comprised of massive basalt rock covered by a thin layer of soil, the peak of Mount Royal is made of faulted, mostly regular shaped prismic blocks chaotically piled upon each other, which hold more moisture, and which promote the growth of plants and trees. So it is that this stone wilderness is covered with a thick forest of shrubs, undergrowth and low trees, between which lovely plants and particularly ferns flourish and proliferate. On the trees climb vines and polypodiums and orchid species with air roots covering the stems. From the branches hang moss and lichen. In the mornings the prevailing south easterly wind often leads to thick mist and rain, which naturally nourishes the eastern slopes, and is the reason why thick forest covers the eastern slopes of Piri and Mount Royal, whereas the dry west winds during the favourable season only allow a thick grassland on the western side." (Leichhardt 1855 p19, 20)

Conclusion

Our Leichhardt project shows that bringing together a reliable body of historical data for a particular location can provide insights and help interpret aspects of the contemporary landscape, and confirms the long term value of careful vegetation and landscape description and the collection and preservation of specimens.

Leichhardt's records of his weeks at Mt Royal culminated in an accurate description of the natural history of a relatively small area of NSW that provides evidence that despite substantial changes in some areas, sites at Mt Royal and Pieries Peak remain much as described 170 years ago. The historical record and the National Park protected lands together provide a base for evaluating future environmental change and management. There are probably few places in Australia as relatively unspoiled by post-European landscape change as Mt Royal, where the landscape was first documented reliably so long ago.

Other aspects of Leichhardt's excursion from Newcastle to Brisbane are not well-known, yet he left a lot of material in his (recently translated) *Diary* (Darragh & Fensham 2013) and writings and a surprisingly large set of specimens from it have survived. It is surprising that such a large body of material has remained unknown, and it deserves serious study. As well as their scientific importance, the herbarium specimens have significant cultural and historical value and provide tangible links with two main driving forces in his life, botany and exploration. There is a strong case for connecting all Leichhardt's plant specimens together as one significant collection, in a global, virtual consolidation of images and other information sources.

Leichhardt was a well read, generalist natural historian with a wide range of scientific interests. He made an extensive contribution to understanding the botany, geology and zoology of NSW. Leichhardt's visit to Mt Royal made a strong impression on him, and left him considering wider phytogeographic and ecological issues. A year later he reflected in a letter written in the Bunya Bunya district of southeast Queensland (to Gaetando Durando in Paris, 6 January 1844 translated from French). "*I visited Mount Royal, one of the spurs of these mountains. It rises to about 3,000 feet* [1200 m] *and is one of the highest mountains in that part of the colony. Mount Royal extends due south from New England on a straight line. Its heart and the conspicuous mass of it are basaltic but its flanks are formed of sandstone. Its eastern slope is covered with dense vegetation of quite an unusual character, called 'mountain brush' in the colony. To my mind, this brush, of which I happen to be making a special study just now, is the same thing as the virgin forests of South America. Waterton's fine description of it in his 'Wanderings in South America' applies quite aptly to the Mt. Royal brush, and even more to the Bunya Bunya mountain brushes. Within a small area you find a great variety of trees, thrusting up to a considerable height before branching, and bound together by just as great a variety of vines that have run right up to spread their leaves and flowers over the crowns of the trees. Herbaceous plants are only found on the margins of the brush, and in spaces open to the light and air. Ferns grow with particular luxuriance and in great variety; and in the little ravines at the base of the mountain, where a mixture of vegetable mould and decomposed basalt has accumulated, Alsophila grows to 15'* [5 m] *in height and 10"* [30 cm] *in thickness. I've a satisfactory collection from these brushes but have not yet determined my plants as I have no books with me.*" (Aurousseau 1968)

Leichhardt's records of his time at Mt Royal provide a surprisingly personal picture of him as a scientist and bushman at an early stage in his career and provide an engaging story of what life was like on the edge of European settlement of Australia. His journey in a landscape then still new to science show his wide skills and interests and provides a legacy of observations on flora and fauna, geological descriptions, weather descriptions and on Aboriginal place names. The Mt Royal journey shows his quest for knowledge, exploration and accurate scientific documentation, together with the misadventures and persistence that were evident in his later explorations.

Acknowledgements

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APPENDIX 1 Leichhardt's Mt Royal plant specimens held at the National Herbarium of NSW (NSW) and National Herbarium of Victoria (MEL), showing Herbarium accession numbers and Leichhardt's specimen notes

Location/Species	**Family**	**Herbarium**	**Specimen number**	*Notes on specimen – likely to be Leichhardt's*
St Clair Station				
Centipeda minima subsp. *minima*	Asteraceae	MEL	2158212A	*Creek at Capt. Maynes*
Gratiola peruviana.	Scrophulariaceae	NSW	232406	Fern Tree groves Jan 1843
Dyrinne				
Dendrobium pugioniforme	Orchidaceae	NSW	590490	brush of Piri
Carro Creek				
Pimelea ligustrina subsp. *ligustrina*	Thymelaeaceae	MEL	0057922A	*brush of Piri and Carrocreek*
Rumex brownii	Polygonaceae	MEL	0610644A	*Corro Creek*
Scleranthus sp. nov.	Caryophyllaceae	MEL	2224100A	*Piri, head of Corro Creek, the Hunter*
Senecio bipinnatisectus	Asteraceae	MEL	0022960A	*Carrocreek*
Senecio bipinnatisectus	Asteraceae	NSW	27837	Carrocreek
Piri forest				
Oplismenus hirtellus	Poaceae	MEL	2137446A	*top of Piri*
Cheilanthes tenuifolia	Pteridaceae	MEL	2152003A	*top of Piri*
Fimbristylis dichotoma	Cyperaceae	MEL	2202787A	*top of Piri*
Acaena agnipila	Rosaceae	MEL	0021829A	*top of Piri*
Desmodium brachypodum	Fabaceae	NSW	105325	top of Piri Jan 43
Platysace lanceolata	Apiaceae	MEL	2253216B	*Piri Forest*
Acacia irrorata subsp. *irrorata*	Fabaceae	MEL	0015520B	*Piri forest*
Sambucus australasica	Caprifoliaceae	MEL	1595210A	*Forest of Piri*
Eucalyptus viminalis	Myrtaceae	NSW	318683	Gums from piri forest Jan 43
Senecio linearifolius var. *arachnoideus*	Asteraceae	NSW	117916	fennel scented Senecio, forest of Piri Jan 43
Piri brush				
Astrotricha latifolia	Araliaceae	MEL	2248276A	*Brush of Piri*
Blechnum patersonii subsp. *patersonii*	Blechnaceae		294108	*piri brush Jan 1843*
Brachychiton acerifolius	Malvaceae	MEL	0070010A	*Glendon. Brush of Piri*
Brachychiton acerifolius	Malvaceae	MEL	0070011A	*brush of Piri*
Caldcluvia paniculosa	Cunoniaceae	MEL	0262703A	*brush of Piri*
Cryptocarya glaucescens	Lauraceae	MEL	0622984A	*brush of Piri*
Cryptocarya obovata	Lauraceae	MEL	0623449A	*Piri brush, Glendon.*
Diploglottis cunninghamii	Sapindaceae	NSW	491210	*leaf of a tree from Piri brush Jan 43*
Doryphora sassafras	Atherospermataceae	MEL	0003252A	*In the brush of Piri*
Dysoxylum	Meliaceae	MEL	0118688A	*Piri Brush*
Elaeocarpus kirtonii	Elaeocarpaceae	MEL	2226631A	*brush of Piri*
Elatostema reticulatum	Urticaceae	MEL	0279920A	*brush of Piri*
Elatostema reticulatum	Urticaceae	NSW	430290	Dorstenia from piri brush Jan 43
Emmenosperma alphitonioides	Rhamnaceae	MEL	0713021A	*brush of Piri*
Lomandra spicata	Asparagaceae	MEL	2216017A	*From Piri brush.*
Vesselowskya rubifolia	Cunoniaceae	NSW	140750	piri brush Jan 1843 together with Dorstenia grateola, Callicoma. Small tree
Kurranulla Creek				
Dictymia brownii	Polypodiaceae	NSW	633371	*Polypodium attached to trees and rocks in the brushes of Piri, Mt Royal, Carrocreek Jan 29, 1843*
Orites excelsus	Proteaceae	NSW	562536	Jan 1843
Marsdenia rostrata	Apocynaceae	NSW	662509	Piri Brush
Sambucus australasica	Adoxaceae	NSW	244528	Piri
Rubus nebulosus	Rosaceae	MEL	0031350A	*Piri*
Ficus coronata	Moraceae	MEL	1063175A	*Piri*
Urtica incisa	Urticaceae	MEL	2042122A	*Piri*
Orites excelsus	Proteaceae	MEL	2176646A	*Piri*
Juncus continuus	Juncaceae	MEL	2187432A	*Piri*
Mt Royal				
Acacia maidenii	Fabaceae	MEL	0580326A	*Mount Royal*
Acaena novae-zelandiae	Rosaceae	MEL	2227445A	*Mount Royal*
Australopyrum pectinatum	Poaceae	MEL	0626893A	*Mount Royal*
Carex declinata	Cyperaceae	MEL	2196656A	*Mount Royal*
Cheilanthes sieberi subsp. *sieberi*	Adiantaceae	NSW	192596	*Mount Royal*

Location/Species	**Family**	**Herbarium**	**Specimen number**	*Notes on specimen – likely to be Leichhardt's*
Echinopogon ovatus	Poaceae	NSW	544464	*Mount Royal; Glendon*
Hedycarya angustifolia	Monimiaceae	NSW	67829	
Lepidosperma laterale	Cyperaceae	MEL	2202853A	*Mount Royal*
Lomandra longifolia subsp. *longifolia*	Asparagaceae	MEL	0025147A	*Mount Royal*
Lomandra longifolia subsp. *longifolia*	Asparagaceae	MEL	0025164A	*Mount Royal*
Notodanthonia longifolia	Poaceae	MEL	2136159A	*Mount Royal*
Ottelia ovalifolia	Hydrocharitaceae	NSW	3447	Mt Royal, Glendon
Pellaea nana	Adiantaceae	NSW	593555	Mount Royal
Polyosma cunninghamii	Escalloniaceae	NSW	628690	Brush of Piri, Jan 1843
Pseudognaphalium luteoalbum	Asteraceae	NSW	685173	*Mount Royal*
Rubus parvifolius	Rosaceae	MEL	0246927B	*Mount Royal*
Rubus rosifolius	Rosaceae	MEL	1058189A	*Mount Royal*
Senecio hispidulus	Asteraceae	NSW	66732	pinnatifid Senecio Jan 43
Sorghum leiocladum	Poaceae	MEL	1548069A	*Mount Royal*
Baybuck				
Cayratia clematidea	Vitaceae	MEL	2244532A	*South cliffs of Bebock*
Clematicissus opaca	Vitaceae	NSW	142499	a vine from the southern cliffs of Bibock near Capt Maynes Jan 29 1843
Cissus opaca	Vitaceae	MEL	2241635A	*From the South Cliffs of Bebock, Capt Maynes*

APPENDIX 2 Chronology of Leichhardt's activities at Mt Royal and weather summary from 23 January to 25 February 1843

During the period of Leichhardt's journey to Mt Royal he experienced dry (drought?) conditions which ended in cloudy and showery weather and heavy rains. The weather described in the *Diary* is confirmed in available newspaper reports. Note that Sydney weather conditions are indicative of broader regional weather patterns and can be used to indicate local weather in the Hunter Valley and at Mt Royal.

Weather reports sourced from the *Sydney Morning Herald* and *Maitland Mercury,* Australian National Library – Trove website – http://trove.nla.gov.au/ndp

Leichhardt's activities	**Weather summary**
Monday 23 January 1843	East/South Easterly winds along coast, dry with some cloud.
Attacked by wild bullock at Glendon. Loses geological hammer.	
Tuesday 24 January 1843	East/South Easterly winds along coast, dry with some cloud.
Travel from Glendon to Captain Mayne's at St Clair. Leichhardt's horse fell with him.	
Wednesday 25 January 1843	East/South Easterly winds along coast, dry with some cloud.
Climbs Dyrrine	
Thursday 26 January 1843	Light East/South Easterly winds along coast, dry with some cloud.
Left Captain Maynes for Piri. On reaching Piri, horse broke bridle and returned to Captain Maynes. Returns via Jump Up Hill and "makes tiring valley and mountain path a second time." Low on provisions.	
Friday 27 January 1843	East/South Easterly winds along coast, dry with some cloud.
Leichhardt searches for horse but could not find it. Companion returns to Glendon to fetch provisions and Leichhardt camps in a hollow 'black butt' tree in grassland and spends 4 days alone accompanied by his dog. Frequently ascended Piri before sunset.	In Wollombi "*There was every appearance of rain in the early part of the week, but none has yet fallen; the verdue consequently looks sickly, and the late maize shows signs of premature forwardness.*"
Saturday 28 January 1843	East/South Easterly winds along coast.
Day 2 alone. Near Piri. Probably climbed Mt Royal.	Wollombi – The Weather – There was every appearance of rain in the early part of the week, but none has yet fallen; the verdue consequently looks sickly, and the late maize shows signs of premature forwardness.
Sunday 29 January 1843	East/South Easterly winds along coast, partly cloudy with some light showers.
Day 3 alone. Camped near creek in ravine which lead down from Jump Up Hill to Carro Creek. Provisions ran out.	
Monday 30 January 1843 (New moon)	East/South Easterly winds along coast, partly cloudy with chance of showers.
Day 4 alone. Returns to Captain Mayne's at St Clair. (herbarium specimen of this date)	
Tuesday 31 January 1843	Light drizzling rain in Singleton.
Captain Mayne's. Rainy day.	Strong East/South Easterly winds along coast, partly cloudy with light rain showers.
Wednesday 1 February 1843	Moderate gusty East/South Easterly winds along coast, partly cloudy with showers.
Captain Mayne's. Rainy day. Probably visited Babock cliffs.	

Leichhardt's activities	**Weather summary**
Thursday 2 February 1843 *After 2 days of rain, during which he stayed at Captain Mayne's, the dray came up from Glendon with provisions. Leichhardt returned with his horse to his hollow tree at Piri. Soon after arriving, a horse went off a second time and Leichhardt had to track it for 10 miles and ride back without a saddle and bridle. Fire destroyed 2 quires of paper and his washed shirt.*	Cloudy with light rain. East/South Easterly winds along coast, partly cloudy with occasional rain. In Singleton "No rain has fallen here since the shower on the 9th of last month, except a little drizzling rain on Tuesday, the 31st. As might be expected, the young corn is rapidly advancing to premature maturity; in some places where the ground was not properly worked previous to planting it has entirely failed. The grass which a few weeks past, had a cheerfully green appearance, is now withered and dry. This day (Thursday) has set in cloudy with occasional slight showers of rain."
Friday 3 February 1843 *Lost pencil and could not write any notes. Rain commenced, and was compelled to send plants home half dry and in order not to lose them, had to follow them about 4–5 days afterwards. Letter notes that threat of rain constrained him to send plant collection back to Glendon by a bullock team that had just come up with provisions for the cedar getters.*	Moderate East/South Easterly winds along coast, with low cloud and showers.
Saturday 4 February 1843 *Stayed in sawyers hut around this time for some days* *Maitland Mercury reports that "there are two bushrangers between Singleton and Maitland, and that they have already robbed a traveller of his horse. Excepting this the district is quiet."*	East/South Easterly winds along coast and high cloud. Some showers.
Sunday 5 February 1843	Strong westerly winds during day, shifting to south overnight along coast.
Monday 6 February 1843	Cloudy with strong winds, humid. Upper Hunter – "The atmosphere has been threatening for rain for some days, but none has fallen. The country from Murrurundi to Singleton is in a deplorable, parched up state, neither grass nor water; and to show the dryness of the season, Glennies Creek, that has always been full of water at the crossing place, near Johnstone's inn, *has now ceased running*; a circumstance the more remarkable as no person ever remembers seeing it so dry before, or void of a running stream."
Tuesday 7 February 1843	Cloudy with south easterly breezes.
Wednesday 8 February 1843	Light easterly winds along coast. Mostly clear with high cloud.
Thursday 9 February 1843	Cloudy with light showers in Singleton, afternoon fine. Light easterly winds along coast.
Friday 10 February 1843	Light easterly winds along coast. In Singleton "The weather still continues dry; although last Thursday set in with slight showers the afternoon was fair. We have had many cloudy days, and fully expected rain, but have not yet been blessed with any."
Saturday 11 February 1843 *Maitland Mercury notes horrible outrage by Blacks at Glendon.*	Cloudy with light easterly winds along coast Singleton – "The weather still continues dry; although last Thursday set in with slight showers the afternoon was fair. We have had many cloudy days, and fully expected rain, but have not yet been blessed with any."
Sunday 12 February 1843 Leichhardt returns to Captain Maynes??	Scattered cloud with light easterly breeze.
Monday 13 February 1843	Westerly winds
Tuesday 14 February 1843	Westerly winds, changing to South Easterly. In Singleton, "Tuesday, the 14th, set in calm, and oppressively warm; in a hot breath of air, was felt, all was still and silent as death, until between two and three o'clock, when the wind suddenly commenced blowing with great force from the southward, bringing with it immense clouds of dust, and towards evening a little rain."

Leichhardt's activities	**Weather summary**
Wednesday 15 February 1843 (Full moon)	South easterly winds along coast. In Singleton, "cloudy and cool, and a few slight showers fell".
Thursday 16 February 1843	In Singleton, "this day has also set in cloudy, with occasional slight showers of rain. Much of the late sown corn is completely destroyed, grass is scanty, and water becoming scarce." Strong south easterly winds along coast.
Friday 17 February 1843 Leichhardt at Glendon again. "*Long rains*" have set in.	East to north easterly winds. Cloudy with rain.
Saturday 18 February 1843 *Begins to press wine at Glendon* *Maitland Mercury reports that "The country between Maitland and Singleton has during the last week been in a state of excitement and alarm, in consequence of the many depredations which have been committed by bushrangers, at various places on the road."*	Easterly winds, cloudy with rain. Singleton – The Weather – Tuesday, the 14th, set in calm, and oppressively warm; in a hot breath of air, was felt, all was still and silent as death, until between two and three o'clock, when the wind suddenly commenced blowing with great force from the southward, bringing with it immense clouds of dust, and towards evening a little rain. The following day was cloudy and cool, and a few slight showers fell; this day has also set in cloudy, with occasional slight showers of rain. Much of the late sown corn is completely destroyed, grass is scanty, and water becoming scarce. February 16. Sydney rainfall 2.73 inches.
Sunday 19 February 1843	Strong easterly winds with heavy rain at times. Sydney rainfall 3.55 inches.
Monday 20 February 1843	Easterly winds with heavy rain at times. Rain in Singleton. Heavy rain in Sydney with rainfall 2.01 inches.
Tuesday 21 February 1843 *Describes attractive 18 year old woman at Captain Maynes who "would make a very desirable spouse and house wife".*	Easterly winds with rain periods. Rain in Singleton. Heavy rain in Sydney with rainfall 3.34 inches.
Wednesday 22 February 1843	Easterly winds with rain. Rain in Singleton. The River Hunter rose at Singleton on Wednesday about ten feet, but on Thursday morning the rain having in some degree abated it began to fall, and has gradually been decreasing.
Thursday 23 February 1843	Easterly winds along coast, some light rain. In Singleton, "during the whole of the last week the rain has been almost unceasing, and from various parts of the country we learn that the overflowing of the creeks has done much mischief." In Wollombi, "During the past week it has rained almost incessantly".
Friday 24 February 1843 Meteor in Sydney noted	Light easterly winds, cloudless.
Saturday 25 February 1843 *Maitland Mercury reports fight amongst the Aborigines – at Glendon*	Light easterly winds, some thunderstorms. The Floods – During the whole of the last week the rain has been almost unceasing, and from various parts of the country we learn that the overflowing of the creeks has done much mischief. The River Hunter rose at Singleton on Wednesday about ten feet, but on Thursday morning the rain having in some degree abated it began to fall, and has gradually been decreasing. In Singleton, "The providential rains which have fallen during the last few days have again raised our hopes of a change for the better in our prospects. The last few months have offered little more to remark on than "Dry weather, and crops failing"; we trust to be able to make a more favourable report in future. Our chances for sown corn are now very good, and for winter feed the present rains are most favourable. The river is up, and bridges down, roads awful; but the cause is so much more valuable than the effect, in reference to those minor subjects, that they only remind us we must make roads and bridges which will not be affected by it."

Appendix 3 Fauna Species Noted By Leichhardt At Mt Royal

Species/ Location	**Leichhardt's notes**
MAMMALS & MONOTREMES	
Rat/ Piri forest	*disturbed us particularly at night, which, however, I was never in a position to observe closely*
Brush-tailed Phascogale?/ Piri forest	*small black animal like a mouse with a foot for jumping and bushy tail, which lives on the trees.*
Greater Glider?/ In ravine	*The flying squirrel chattered*
Wallaroo/ On Piri	*As the sun sank, Wallaroos cam out of the thicket to graze on the beautiful grass*
Potoroo/ Carrow Brook	*Consumed a Hypsiprymus with good appetite at the foot of the mountain. It tastes extremely tender if it is roasted quickly by a very hot fire. Tender, palatable flesh but requires some spices.*
Wallabi/ On Piri	
Platypus/ Carrow Brook	*Ornithorhynchus lived in banks of the deep waterholes*
BIRDS	
Bowerbird?/ St Clair Station	*Mutton birds at St Clair station*
Raven/ St Clair Station	*St Clair station*
Magpies/ St Clair Station	*St Clair station*
Sulphur Crested Cockatoos/ St Clair Station	*Next morning the wheat fields were covered with flocks of white cockatoos, which rose shrieking at the slightest suspicion and now withdrew like a mass of snow to the neighbouring Casuarinas and Angophoras*
Crimson rosellas?/ Forest ravine	*In the morning parrots raise their incessant noise*
Black or Glossy Black Cockatoo?/ Forest ravine	*The cockatoo sweeps screeching over the highest crowns of the trees*
Lyre bird/ Piri forest	*The lyrebird mimicked the call of other birds and the sawyers. Usually it is a simple call like that of a running hen*
Pied Currawong?/ Mt Royal	*One of the birds on the mountain frequently attracted attention. It usually called che a che a che aura.*
Brush Turkey/ Piri brush	*The native turkey is here as well.*
Wedge tailed Eagle/ On Piri	*One evening as I went along on the highest ridge of Piri, an eagle passed over me in tranquil flight*
OTHER	
Flies/ Piri forest	*An extremely large white and black horse fly pestered the horse extremely and was probably the cause of its running away. Three pairs of white patches on the abdomen. Another horsefly with metallic brown abdomen was seen frequently. Blowflies and others flying numerously around me. A small kind of fly swarmed over the horse dung, red-headed with black apices on the wing.*
Lizards/ Forest ravine & Piri forest	*Dry fallen foliage, through which small quadrupeds and lizards moved rustling here and there. A small lizard had taken possession of my hollow tree which my zoological curiosity compelled me to kill. It was very smooth with brown back and blackish flanks*
Tiger snake?/ Piri forest	*Edwards had killed a 5' long snake, which showed bright yellowish transverse stripes on brownish ground colour*
Spiders/ Piri forest	*Spider with red feet and red thorax and black abdomen under the tree trunk*
Other insects/ Piri forest	*Cicadas. Also, I found a grey grasshopper with very long antennae*
Crabs [presumably yabbies]/ Piri brush	*Crabs live in the damp ground.*
Beetles/ Piri forest	*A small white staphylium, just as a somewhat larger beetle which seemed to me to have short wing covers of yellowish colour. A small red beetle with black patches*
Caterpillars/ Piri forest	*I observed a geometer moth caterpillar. It is green, at the front and back pyramidal, fine black undulating longitudinal lines and spots on the back and venter. On the venter a white middle streak, fine similar ones with red spots on the respiratory holes on each side. It seemed to intend to imitate a twig, as it extended about 45 degrees from the tree*
Leeches/ Piri forest	*A crowd of insects in the decayed wood, small leeches with three yellow stripes over the back creep along it, when you go through the bush after the rain.*
Ticks/ Piri forest	*Ticks were ready to attach themselves almost to every animal from humans to insects.*

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Upland wetlands in the Namoi Catchment: mapping distribution and disturbance classes of fens, bogs and lagoons

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Abstract: To assist with planning and conservation strategies, mapping of wetlands above 700 m elevation across the Namoi Catchment (east of Tamworth) was undertaken. The number of hectares of each type within this high-elevation region, the area currently in conservation reserves and the status of these remnants was assessed. 1 001 wetlands were mapped and allocated to three wetland types (fens, bogs and lagoons) and six disturbance groups (based on agricultural clearing and presence of dams). Total wetlands cover was 4 490 ha, of which fens were the most common, followed by bogs and a single lagoon. The smallest wetland was 0.12 ha in size, the largest 113 ha and the average 5 ha. Only 10% of all wetlands were considered to be in near natural state with only 5.5% of all wetland area protected within conservation reserves.

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Introduction

Only a very small amount of the Australian land area is montane environment; much of this occurs along a belt of uplift on the eastern seaboard known as the Great Dividing Range (extending from Cape York Peninsula south to Tasmania). The New England Tableland Bioregion forms a major part of this upland area, incorporating an area of about three million hectares (3,004,202 ha), about 3.6% of the state of New South Wales. Three broad categories of freshwater wetlands locally known as lagoons, fens and bogs occur in this region (Hunter & Bell 2007; Bell *et al.* 2008; Hunter & Bell 2009). In conservation terms all of these wetland types are considered threatened.

The lagoons are shallow temporary lentic wetlands occurring at altitudes above 900 m dominated by emergent macrophytes (Bell *et al.* 2008). They are mostly oval-shaped, often with a distinct rocky margin, with considerable recent silt accumulation on their edges, in some cases forming sand dunes or clay-rich mounts on their eastern side called 'lunettes' (Brock *et al.* 1999; Bell *et al.* 2008). Water is received from small catchments by a combination of hydrological processes; some are mainly stream-fed, some spring-fed and some fed by overland flow. They are largely closed systems though water may spill into adjoining major river catchments. Based on extensive historical and recent field work only 58 lagoons have been identified within the New England Tablelands Bioregion of which only 28% are believed to be intact and in good condition (Bell *et al.* 2008).

Fens are found along watercourses on flat or concave valley floors from altitudes generally above 400 m; the waters that feed them are comparatively mineral rich, alkaline or moderately acidic (Beadle 1981; Keith 2004; Hunter & Bell 2009). Fens are dominated by soft-leaved tussock sedges (usually *Carex* species), grasses and semi-aquatic herbs and lack a sclerophyllous shrub component (Hunter & Bell 2009). Prior to the current work Hunter & Bell (2009) estimated that approximately 5 000 ha of fens occurred in the New England Tablelands Bioregion with only 0.2% of these in conservation reserves.

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Bogs occur generally above 800 m elevation, on a broader range of physiographic positions with waters that are acidic and nutrient poor (Keith 2004;Whinam & Hope 2005; Hunter & Bell 2007). These bogs are structurally dominated by sclerophyllous shrubs (Hunter & Bell 2007). Bogs are thought to be the more common wetland type within the New England Tablelands Bioregion potentially occupying 10 000 ha of which 27% is within conservation reserves and potentially 80% of its original extent intact (Benson & Ashby 2000; Hunter & Bell 2007).

Australian montane wetlands are significant due to their rarity within the landscape; they are also under threat from continuing anthropogenic landuse practices such as grazing, draining, burning, dam construction, digging by pigs, nutrient addition and by climate change (Benson & Ashby 2000; Whinam *et al.* 2001; Whinam & Chilcott 2002; Hope & Kershaw 2005; Hunter & Bell 2007; Bell *et al.* 2008; Hunter & Bell 2009, Hunter & Bell 2013). All three wetland systems are included in listed Endangered Ecological Communities under the *New South Wales*

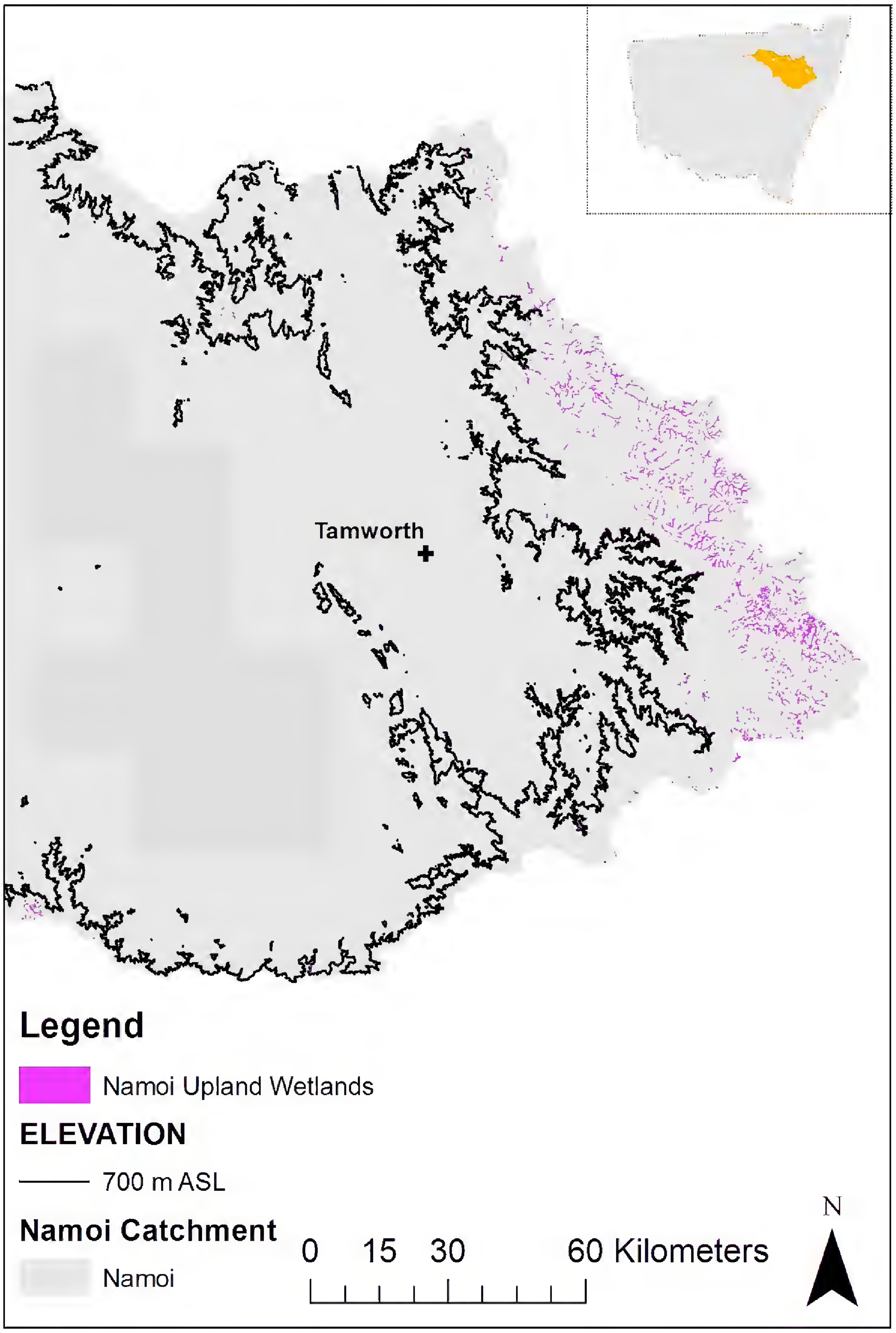

Fig. 1. The eastern half of the Namoi Catchment showing the location and mapping of Upland Wetlands above 700 m elevation along the eastern edge.

Threatened Species Conservation Act (1995). Bogs and Fens dominated by *Carex gaudichaudiana* (Hunter & Bell 2009) are incorporated within the *Montane Peatlands and swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps Bioregions* Endangered Ecological Community determination. Fens not dominated by *Carex gaudichaudiana* are listed within *Carex Sedgelands of the New England Tableland, Nandewar, Brigalow Belt South and NSW North Coast Bioregions* community. Lagoons are listed under *Upland Wetlands of the Drainage Divide of the New England Tableland Bioregion* but are also listed on the Federal *Environmental Protection and Biodiversity* Act as *Upland wetlands of the New England Tablelands and the Monaro Plateau.*

Due to the paucity of information on the distribution of these wetland types and to assist planning and conservation strategies, a pilot project was undertaken to map the current distribution of the three wetland types in the Upland (above 700 m) regions of the Namoi Catchment. The aims were to assess the area of each wetland type, how much is currently in conservation reserves, and the status of these remnants. The Namoi region was chosen as it was a designated priority area for Namoi Catchment Management Authority funding for landholders protecting wetlands in this region. Furthermore the region has an abundance of wetlands under various management titles allowing testing of the efficacy of mapping wetlands for wider application throughout the New England Tableland Bioregion. This paper reports on the results of that study.

Methods

In May 2012 available SPOT5 imagery (created 2006–2007) covering the Upland regions (above 700 m elevation) within the Namoi Catchment in northern New South Wales (Fig. 1) was extensively searched for wetlands. The Upland region lies to the south and west of the township of Uralla and covers areas to the east of Bingara, Bundarra, Tamworth, Nundle and parts of the Liverpool Range. At the time this was the only imagery to have complete coverage of the research area and the only images made available to the author. All wetlands discernible were digitised on-screen within ArcGIS 10.1 (projection: MGA Zone 56). In order to accurately capture the extent of the wetlands on-screen digitising and visualisation generally occurred at a scale of 1:10 000. As part of the mapping routine wetlands were scored for potential wetland type (Lagoon, Fen or Bog) and for degree of disturbance based on amount of surrounding vegetation cover and presence or absence of dams. The author's previous mapping experience, along with extensive on-ground wetland verification investigations during earlier survey and mapping exercises (in particular Hunter 2005; Hunter 2012) greatly assisted the identification of types but additional on-ground verification was also undertaken during the current mapping exercise (approximately four days fieldwork).

Six disturbance classes within two main groups were scored for each mapped wetland. Wetlands were scored for disturbance based on whether they occurred in a largely cleared landscape (less than 30% original surrounding vegetation cover), or whether they were found within primarily native vegetation (> 30% of the original vegetation extant). Wetlands were then scored for presence of any dam within or on their boundary, if a dam was found within 150 m of the wetland boundary, or if the wetland had no dam in or within 150 m of any mapped boundary. Wetlands were scored as conserved if they occurred in conservation reserves under the management of the NSW Office of Environment and Heritage, or were from known Voluntary Conservation Areas.

Results

In total 1 001 wetland polygons covering 4 490 ha corresponded to the three wetland types (Fens, Bogs & Lagoons) and were identified and mapped (Table 1). The smallest wetland was 0.12 ha in size with the largest being 113 ha. Average wetland size was 5 ha.

Fens accounted for the majority of wetlands mapped, accounting for 98.2% of the wetland area and 976 wetlands (Tables 1 & 2). Only 3.8% (134.6 ha) of mapped fen area was within lands reserved for conservation. Of the 1 001 wetlands, 24 (covering 81 ha) were mapped as bogs (1.8% of all mapped wetlands). Of these 99% were within lands reserved for conservation (Tables 1 & 2). Bogs were restricted to the far southern boundary of the Namoi catchment with the majority in Coolah Tops National Park. Only a single lagoon (0.2 ha) was recorded from the Namoi Catchment (Tables 1 & 2). In total 5.5% of all wetland area is within conservation reserves (Table 1).

Only 13% of all wetlands were found within largely native vegetation (Table 2) and 10% of the wetlands were within intact native vegetation and not influenced by a dam within their boundaries or within 150 m of their boundary (Table 2). 37% of all wetlands had a dam within their boundaries.

The results of the mapping project are considered highly accurate, due mainly to the extensive on-ground investigations and mapping of these wetlands previously conducted by the author, both in the Namoi region and across the upland areas of the New England Tableland Bioregion. However some wetlands may have been overlooked, some obscured by dense vegetation overstorey cover, or highly degraded wetlands dominated by introduced grasses and lacking characteristic wetland features. Intergrade wetlands where bog and fen elements occurred within the one wetland, though rare, have been found within the southern parts of the study area (*pers. obs.*). These intergrade wetlands may be due to natural influences or caused by human-induced changes in nutrient status and/or disturbance of substrates (Hunter & Bell 2007; 2009). These are difficult to quantify in mapping and the area of bogs could have been underestimated as such areas were most likely to be included as fens during this exercise. However the results are unlikely to have been unduly affected. Such areas could not be directly mapped and would require on ground investigations.

Table 1. Characteristics of the Upland Wetland types mapped in the Namoi catchment (>700 m elevation): area and proportion in conservation reserves

Wetland type	Total area (ha)	Proportion of mapped wetland area	Area in conservation reserves (ha)	Proportion reserved
Bog	81	2 %	80	99 %
Fen	4 409	98 %	134	4 %
Lagoon	0.2	<.01 %	0	0 %
Total	4 490	100 %	215	6 %

Table 2. The number and type of upland wetlands recorded in the six disturbance categories in the Namoi catchment (>700 m elevation) (1=most disturbed, 6=least disturbed).

Disturbance category	Bog	Fen	Lagoon	Total
1. Cleared & Dam	0	358	0	358
2. Cleared & Dam within 150 m	0	109	0	109
3. Cleared no Dam	0	400	0	400
4. Native Vegetation & Dam	0	16	0	16
5. Native Vegetation & Dam within 150 m	0	14	0	14
6. Native Vegetation, no Dam	24	79	1	104
Total	24	976	1	1001

Discussion

Previous mapping of Upland Wetlands (above 700 m elevation) within the Namoi Catchment by Ecological Australia (2009), was undertaken using the same imagery and methods as used in this current project, but described only 131 wetlands of which 35 were considered artificial (i.e. only 96 were natural wetlands). Sizes ranged from 0.25 ha to 110 ha with a mean of 11 ha (though the methodology states no wetlands under 1 ha were mapped). In the current mapping investigation the range of sizes was similar (0.12 – 113 ha) though the mean size was lower (5 ha). The current mapping however recorded 1 001 natural wetlands, of which 626 wetlands were over 1 ha in size (if constrained to wetland > 0.25 ha, 925 wetlands were mapped). The numbers of wetlands found in this survey therefore far exceed those presented by Ecological Australia (2009).

Only one wetland is listed under the *EPBC* Act, a lagoon 0.2 ha in size (called South Head by Bell *et al.* (2008)). The reservation of this isolated lagoon is important and measures should be taken to secure its continued persistence; only 58 lagoons in total are known from the New England Bioregion (Bell *et al.* 2008), the nearest lagoon to South Head being 43 km distant.

Hunter & Bell (2009) postulated that as little as 5 000 ha of fens occurred in the New England Bioregion, but although the upland areas of the Namoi Catchment are a prime area for the occurrence of fens, it is obvious from the results here (4 400 ha are found in this region alone) that this number was an underestimate. Based on the current mapping it is likely that the New England Bioregion probably contains an order of magnitude more fens than previously thought; it is suggested here that there is likely to be 30 000 – 50 000 ha of fens across the New England Bioregion.

Within the Namoi Catchment the proportion of fens protected in conservation reserves is about 4 %; higher than Hunter & Bell (2009)'s assessment that 0.2% of fens in the New England Bioregion were within conservation reserves. This discrepancy may be a local phenomenon, due to recent acquisitions (since 2009) of Crown lands for conservation reserves that include large fens and significantly increased the protection of fens within the Namoi. However 4 % is still a very low level of reservation, and as only 10 % of all fens within the upland Namoi Catchment are relatively undisturbed i.e. within largely native vegetation and unaffected by dams, further reservation of fens through conservation mechanisms such as Voluntary Conservation Agreements is still a priority.

For the New England Bioregion Hunter and Bell (2007) considered bogs to be better reserved than fens, and within the Namoi study region nearly all bogs were in reserves and unaffected by dams or agricultural clearing. Bogs were largely restricted to high altitude locations along the southern boundary of the Namoi Catchment such as in the Coolah Tops (Binns 1997) and the Ben Halls Gap areas (Whinam & Chilcott 2002).

This mapping program has highlighted that fens occupy a larger area than previously thought, however that they are still a highly unrepresented community type within the reserve system. Only 8% of fen wetlands within the Namoi Catchment are in near natural condition (Table 2). Bogs on the other hand are rarer within the Namoi Catchment but are well reserved, in good condition and therefore of a lesser reservation priority within this region. As only a single lagoon occurs within the Namoi Catchment it is a priority that this is protected in the near future. The success of this pilot study indicates that this mapping could be extended across the rest of the New England region and with the use of better imagery such as ADS40 better understanding and more efficient prioritisation of conservation activities could occur.

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Impact of broom, *Cytisus scoparius* (Fabaceae), in naturally treeless sub-alpine frost-hollow vegetation communities at the Barrington Tops, south-eastern Australia

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Abstract: The exotic shrub *Cytisus scoparius* (L.) Link (family Fabaceae), known as broom, is having a major impact on native vegetation in naturally treeless sub-alpine frost-hollow areas (c. 32° 01’ 37” S, 151° 26’ 12” E’, 1440 m elevation) at the Barrington Tops, New South Wales, in south-eastern Australia. This vegetation is of limited extent and has significant biogeographical and ecological importance. Nine paired 10 m line transects were compared, with one of the pair in areas of almost 100% *Cytisus scoparius* and the other in adjacent areas without *Cytisus scoparius*. Results were compared with species recorded from this area in the 1930s. There are obvious differences in native vegetation in areas with and without *Cytisus scoparius*. On average there were 5.1 (range 2–10) species per 10 m in areas of almost 100% *Cytisus scoparius* cover and 17.0 (12–25) species per 10 m in areas adjacent to infested areas but without *Cytisus scoparius*. Other than *Cytisus scoparius*, the area surveyed had little in the way of exotic species and these were only present at low densities. Native species present in 2008 are similar to those recorded in the 1930s; there were no records of *Cytisus scoparius* in the area in the 1930s. The study suggests that control of *Cytisus scoparius* in naturally treeless areas at the Barrington Tops should be a priority to prevent a decline in the distribution and abundance of many plant species, many of which only occur in treeless areas of the Barrington Tops.

Keywords: *Cytisus scoparius*; broom; weed impact; vegetation change; Barrington Tops; frost-hollow vegetation.

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Introduction

The exotic shrub *Cytisus scoparius* (L.) Link, (family Fabaceae) known as broom, is native to Europe but has naturalised and is a weed in many countries around the world including Australia, New Zealand, U.S.A., Canada, India, Iran, Japan, South Africa, Argentina and Chile (Parsons & Cuthbertson 1992, Gómez-Sosa in Zuloaga & Morrone 1999, Arroyo *et al.* in Mooney & Hobbs 2000, Ohashi in Iwatsuki *et al.* 2001). A summary of information on *Cytisus scoparius* in Australia until 1998 can be found in Hosking *et al.* (1998). Since that time there have been a number of other published studies on *Cytisus scoparius* in Australia (Fogarty & Facelli 1999, Downey & Smith 2000, Sheppard & Hosking 2000, Sheppard *et al.* 2002, Paynter *et al.* 2003, Wearne & Morgan 2004, 2006, Stokes *et al.* 2006). In New South Wales the invasion and establishment of *Cytisus scoparius* has been listed as a key threatening process in schedule 3 of the *NSW Threatened Species Conservation Act 1995* (DECC 2008).

The Barrington Tops sub-alpine plateau ranging in elevation from 1300 m to 1586 m is situated in south-eastern Australia, on the northern side of the Hunter Valley, New South Wales (Figure 1). Vegetation on the sub-alpine plateau has been geographically isolated from other high altitude eastern Australian areas and has many endemic species.

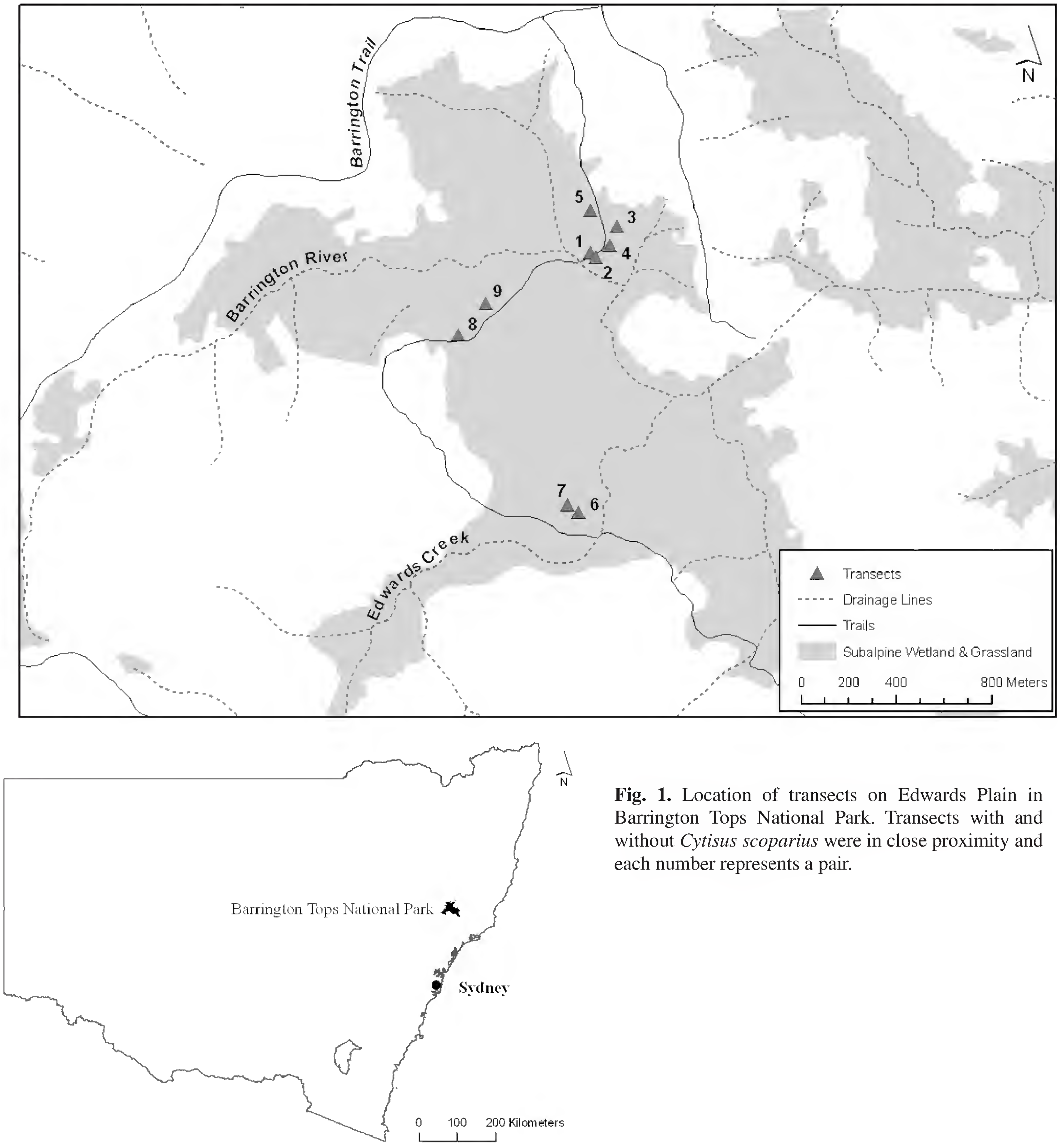

Fig. 1. Location of transects on Edwards Plain in Barrington Tops National Park. Transects with and without *Cytisus scoparius* were in close proximity and each number represents a pair.

On the Barrington Tops an extensive *Cytisus scoparius* infestation is displacing native vegetation. The species is believed to have been grown on the property 'Tomalla' in the 1840s and was not observed far south of 'Tomalla' before the late 1940s (Waterhouse 1988). According to references in Waterhouse (1988) expansion in range and density of *Cytisus scoparius* seems to have taken place since 1969 when the southern end of the plateau became a National Park and seasonal grazing and associated burning ceased. It now occupies over 10 000 ha of sub-alpine plateau on the Barrington Tops and is continuing to spread (OEH 2011). Management of *Cytisus scoparius* has been undertaken since the 1970s with varying levels of success (Schroder & Howard 2000, Odom *et al.* 2003).

The establishment and expansion of *Cytisus scoparius* in the treeless vegetation community has occurred over the past twenty years with very little understanding of the impacts on native vegetation. Waterhouse (1988) discussed the impact of *Cytisus scoparius* on trees but did not detail the impact on other species. Our work is the first study covering the impact of *Cytisus scoparius* on naturally treeless areas of the Barrington Tops. The only previously published information on vegetation in grasslands adjoining swamps and below woodlands on the Barrington Tops, the area covered by this study, is in the pioneering ecological work of Fraser & Vickery (1939) though many of the species names that they use have subsequently changed. Heinrich & Dowling (2000) focussed on known rare and threatened plant species in the montane wetlands and peatlands that occur below the naturally treeless vegetation communities. The montane wetlands and peatlands are listed as an Endangered Ecological Community under the NSW *Threatened Species Conservation Act (1995)*.

Since the mid 1980s management of *Cytisus scoparius* on the Barrington Tops has focussed on containment including control along tracks and trails and preventing its dispersal into non-infected catchments. *Cytisus scoparius* control has been undertaken in the montane wetlands that adjoin the treeless vegetation. Following Heinrich & Dowling's (2000) survey work in 1998 control of *Cytisus scoparius* within the wetlands and adjoining vegetation, including areas of naturally treeless sub-alpine frost-hollow vegetation, was expanded (Schroder & Howard 2000, DECC 2010). The objective of this study was to determine the impact of *Cytisus scoparius* on the native vegetation of naturally treeless sub-alpine frost-hollow vegetation.

Methods

Study area

The climate on the Barrington Tops plateau has sub-alpine influences with rainfall ranging from 1000 mm/yr in the north west to about 2000 mm/yr in the south east. Average temperatures on the plateau above 1300 m range from -2 to 9° C in July to 9 to 23° C in January (CMPS & F Environmental 1995). Snowfalls occur in winter above 1100 m as a result of cold fronts. Summers can be warm but temperatures above 30°C are rare.

The study area was on Edwards Plain (c. 32° 01' 37" S, 151° 26' 12" E) about 1440 m above sea level, at the southern end of the Barrington Tops plateau in Barrington Tops National Park (Figure 1). Soil on the plain is a brown humic loam with no substrate evident. The study area is one of a number of low lying areas at higher elevation where cold air ponding occurs. It is a naturally treeless plain between woodland and swampy areas alongside the Barrington River and its tributaries. In recent times this area has been increasingly invaded by *Cytisus scoparius*; mapping of this species in 1989 and 1999 demonstrated a gradual invasion into the treeless vegetation areas (Odom *et al.* 2003, DECC 2010).

Vegetation sampling

This study was undertaken in February 2008. Previously twenty 20 m long line transects had been surveyed from 2003 in different types of *Cytisus scoparius* invaded vegetation on the Barrington Tops (Hosking & Shroder unpubl). Impacts of *Cytisus scoparius* shown in that study varied considerably between different vegetation communities and the present study was devised to examine *Cytisus scoparius* impact in the area where impact appeared to be greatest.

Line transects were used in this study (and studies that began in 2003) as this was believed to give more accurate information on ground cover than use of other vegetation sampling techniques and also prevented trampling of native vegetation which may have impeded identification of smaller plants. Eighteen transects were used, each 10 m long, 9 in *Cytisus scoparius* infested areas, and 9 in adjacent areas that had not been invaded by *Cytisus scoparius*. The first half of the first transect that began in 2003 corresponds to the first *Cytisus scoparius* transect of this study. Centimetres of line cover by each species was determined for each metre and converted to a percentage cover for each transect. *Cytisus scoparius* in this area grows to around 2 m high and forms a dense canopy. For each vertical projection of the edge of the tape each species was recorded only once so that species do not exceed 100 percent ground cover. As species overlapped in many areas cover for all species in each transect could be greater than 100 percent.

Comparison of *Cytisus scoparius* infested transects with those from sites without this species was conducted with nonmetric multi-dimensional scaling (NMDS) (Fasham 1977, Prentice 1977), a multivariate analysis technique that, in this case, examined the complexity of species composition along each of the 18 transects. The complexity of these plant communities was based on the presence, and relative abundance, of each of 49 identified species, excluding *Cytisus scoparius*, within each metre of each of the 18 transects examined.

In December 2007 the *Cytisus scoparius* infested areas had been sprayed with triclopyr (Garlon® 600 at 170 ml per 100 litres). This is not thought to have influenced the species present, as data from 2003 to 2007 for the first *Cytisus scoparius* infested transect showed few species. This transect, nor any other transect in the 2008 study, showed evidence of ever being treated with herbicide prior to December 2007. Where transect cover with dead and dying *Cytisus scoparius* plants was continuous, transect cover was considered to be 100% though as a vertical projection this would have been slightly less. Determination of actual cover in such areas would have been extremely difficult and would not have been accurate. As a result of spraying *Cytisus scoparius* leaves had largely been shed by dying plants and this probably increased density of *Poa sieberiana* through increased light reaching plants below the *Cytisus scoparius* canopy. There were no remains of sprayed plants other than *Cytisus scoparius* evident in sprayed areas despite it being only 2 months after spraying. The age of *Cytisus scoparius* plants with large stem diameters in close proximity to transects was assessed by counting yearly growth rings of three randomly selected shrubs for each *Cytisus scoparius* infested transect.

Plant identification is based on years of plant collecting, mostly by J.R. Hosking, at the Barrington Tops. Names used here follow those used in PlantNET (http://plantnet.rbgsyd.nsw.gov.au/). Herbarium codes follow Holmgren *et al.* (1990). Vouchers of all the species listed are held at the National Herbarium of New South Wales (coded NSW) and in most cases also at the Australian National Herbarium (CANB), the National Herbarium of Victoria (MEL) and the herbarium of the University of New England (NE).

Species composition in this area in the 1930s

Comparisons are made with species listed for this area by Fraser & Vickery (1939) who compiled lists of species that occurred in various areas in the upper Williams River and the Barrington Tops districts. Their lists do not appear to be based on transect data but appear to be the result of observations made on numerous trips to the area. This information is used to compare differences and similarities in species present in the 1930s and at the time of this study. There have been considerable advances in plant taxonomy since 1939 and fortunately Fraser & Vickery collected specimens (now lodged at NSW and the University of Sydney (SYD) that enabled comparisons to be made between the two studies. In some cases it was not possible to relate the name used by Fraser & Vickery to those of this study as no voucher specimens for collections made from the area before 1939 are present at NSW and SYD, and the species that they listed is not known to occur in the area.

Data analysis

Transect data, consisting of lengths of transect covered by identified plant species, were converted to an ordinal format based on the relative abundance of each species. The presence of *Cytisus scoparius*, because of its dominance in

Fig. 2. *Tetrarrhenia turfosa*, a grass only recorded from treeless areas and rarely found in areas impacted by *Cytisus scoparius* at the Barrington Tops.

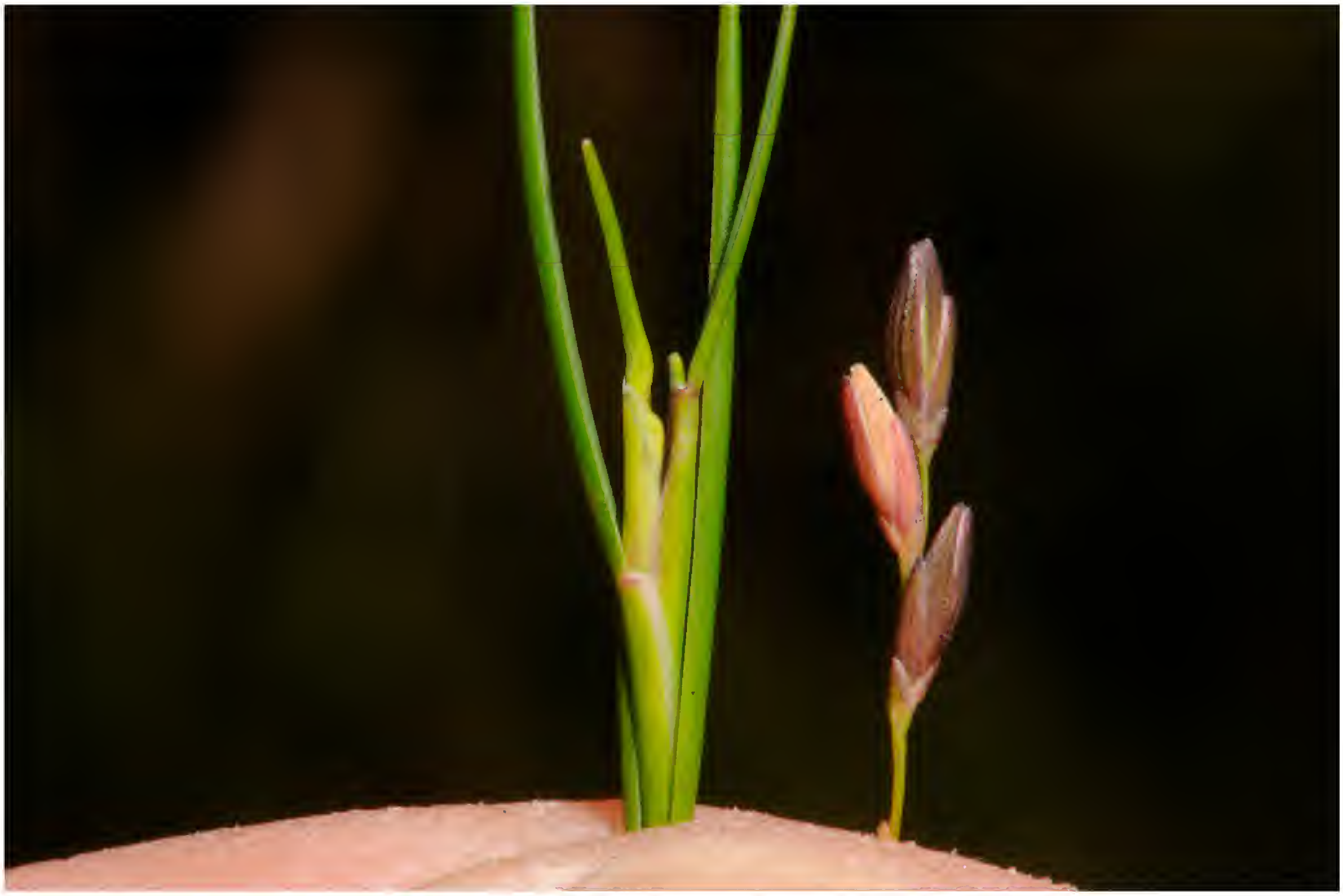

Table 1. Plant species cover in February 2008 in open plains transects without *Cytisus scoparius* on Edwards Plain, Barrington Tops National Park. Collection numbers are given for species without a name currently.

Genus / species (family (subfamily)) * = naturalised	**Cover in transects (%)**									**Total Cover (%)**
	1	2	3	4	5	6	7	8	9	
Poa sieberiana (Poaceae)	89	92	91	91	69.5	54	63.7	100	86	81.80
Empodisma minus (Restionaceae)			5	49.5	48	65.5	39.7	0.6		23.14
Tetrarrhena turfosa (Poaceae)		1.1	20.3		68	1.3	17.9	0.2	3.8	12.51
Carex sp. (JRHosking 2585 *et al.*) (Cyperaceae)	3	2.9	0.3	1.6	2.4	3.1	2.7	1.9	4.8	2.52
Oreomyrrhis eriopoda (Apiaceae)	7.2	4.7	1.1	0.7			0.9	3.3	1.7	2.18
Scaevola hookeri (Goodeniaceae)				1.9					15.5	1.93
Pultenaea fasciculata (Fabaceae (Faboideae))	0.5					7.4	4.5			1.38
Epacris breviflora (Ericaceae (Epacridoideae))						7.5	4.7			1.36
Hakea microcarpa (Proteaceae)						6.2	0.2	5		1.27
Erigeron bellidioides (Asteraceae)				0.3			10.4	0.1		1.20
Leucopogon pilifer (Ericaceae (Epacridoideae))	2.9	1.3	0.1	1.7	0.2	2.4	1.4		0.1	1.12
Coronidium scorpioides (Asteraceae)	3.3	2.4	0.2	1.7			0.1	0.2	0.7	0.96
Rytidosperma penicillatum (Poaceae)	6.8	0.1		0.2					0.9	0.89
Luzula modesta (Juncaceae)					0.3					0.79
Luzula densiflora &/or *L. meridionalis* (Juncaceae)			0.1	0.4		2	2.1	2.2		0.76
Wahlenbergia ceracea (Campanulaceae (Campanuloideae))	0.4	0.3	0.6	0.8	0.7	1.1	0.9	1.3	0.5	0.73
Craspedia variabilis (Asteraceae)	0.7	0.5	3.3	1.1		0.3	0.5			0.71
Mitrasacme serpyllifolia (Loganiaceae)			0.1	0.5		4				0.51
Hydrocotyle peduncularis (Araliaceae)		0.1		0.7	0.2	0.1		1	0.9	0.33
Carex sp. (JRHosking 2873) (Cyperaceae)	0.4		0.4	0.1	0.3	1	0.1		0.1	0.27
Gentianella barringtonensis (Gentianaceae)	0.2			0.3	0.9	0.2	0.2	0.3		0.23
Euchiton involucratus (Asteraceae)				0.4				1	0.2	0.18
Ranunculus lappaceus (Ranunculaceae)				0.1				1.4		0.17
**Hypochaeris radicata* (Asteraceae)	0.9								0.5	0.16
Euphrasia ciliolata (Orobanchaceae)				0.1				0.2	0.8	0.12
Xerochrysum bracteata with yellow involucral bracts (JRHosking 2586 *et al.*) (Asteraceae)	0.9						0.1			0.11
Microlaena stipoides var. *stipoides* (Poaceae)			0.7	0.1						0.09
Arthropodium milleflorum (Asparagaceae (Lomandroideae))	0.5	0.2								0.08
Deyeuxia gunniana (Poaceae)				0.2	0.1	0.1			0.3	0.08
Dichelachne inaequiglumis (Poaceae)				0.5						0.06
Solenogyne gunnii (Asteraceae)									0.5	0.06
Acaena novae-zelandiae (Rosaceae (Rosoideae))								0.4		0.04
Scleranthus sp. (JRHosking 2489) (Caryophyllaceae)								0.1	0.3	0.04
Viola betonicifolia subsp. *betonicifolia* (Violaceae)				0.4						0.04
Dichondra repens (Convolvulaceae)									0.3	0.03
Hypoxis hygrometrica var. *hygrometrica* (Hypoxidaceae)				0.1					0.2	0.03
Xerochrysum bracteata with white involucral bracts (JRHosking 3202) (Asteraceae)							0.3			0.03
Unidentified Monocotyledon					0.3					0.03
Viola fuscoviolacea (Violaceae)									0.2	0.02
Ajuga sp. (JRHosking 2314 & JMBakonji) (Lamiaceae)									0.1	0.01
**Cerastium vulgare* (Caryophyllaceae)								0.1		0.01
Gonocarpus humilis (Haloragaceae)				0.1						0.01
Leucopogon fraseri (Ericaceae (Epacridoideae))	0.1									0.01
Pterostylis sp. (Orchidaceae)	0.1									0.01
Rytidosperma laeve (Poaceae)						0.1				0.01
**Trifolium repens* (Fabaceae (Faboideae))	0.1									0.01
Velleia montana (Goodeniaceae)		0.1								0.01
Number of species	17	12	13	25	12	17	18	18	21	
Groundcover for all species	117	106	123	155	191	156	150	119	118	
Groundcover for species other than *Poa sieberiana*	28	13	32	64	121	102	87	19	32	

transects where it was present, was ignored, allowing greater emphasis to be placed on the other species present.

A Euclidean distance matrix, created from the ordinal transect data with primary treatment of ties, was used to describe the similarities between transects based on the relative abundance of identified vegetation species. There is no transformation of these ordinal data – converting categorical data to a metric scale is not recommended.

Results

Impact of Cytisus scoparius on native species

Our results show major differences in species richness and species groundcover in transects with and without *Cytisus scoparius* (Figures 3 and 4). Species richness in line transects with almost 100% *Cytisus scoparius* cover was 5.1 species per 10 m (range 2–10) while in adjacent uninfested transects species richness was 17.0 species per 10 m (range 12–25) (Figure 3). Groundcover of species other than *Poa sieberiana* was also severely impacted with on average 4% ground cover (range 0–19%) in areas with close to 100% *Cytisus scoparius* cover. In adjacent uninfested areas groundcover was 55 % (range 19–121%) (Figure 4).

A total of 44 native species (and 3 exotics) were recorded from the nine transects without *Cytisus scoparius* (Table 1). Cover of *Poa sieberiana* ranged from 54–100% for all transects without *Cytisus scoparius*. *Empodisma minus* (up to 65%) and *Tetrarrhena turfosa* (up to 68 %) (Figure 2) were also common. Other species are less frequent; 36 species had less than 1% groundcover.

In comparison transects with *Cytisus scoparius* had few other species present, and groundcover was dominated by *Poa sieberiana* (83% cover) (Table 2). At the time of measuring cover in these transects herbicide treatment 2 months earlier appeared to have killed most of the standing *Cytisus scoparius* but there were a small number of *Cytisus scoparius* seedlings present and a few *Cytisus scoparius* branches had not died. A total of 14 native species (and 1 exotic in addition to *Cytisus scoparius*) were recorded from the nine transects with *Cytisus scoparius*. Only the tall shrub *Hakea microcarpa* (1.4%) and the grass *Microlaena stipoides* (1.5%) had cover greater than 1%. There was very little *Tetrarrhena turfosa* and no *Empodisma minus* recorded. *Hakea microcarpa* did not appear to be greatly affected by the *Cytisus scoparius* herbicide treatment.

The non-metric multidimensional scaling (NMDS) analysis produces an ordination diagram (see Figure 5) which is a graphical representation of the information in the distance matrix. Similarities between samples (*i.e.* transects) are indicated by the relative closeness of the plotted points on the ordination diagram. The stress associated with Figure 5 (*i.e.* 0.0887) indicates the configuration provides a good representation of the actual dissimilarities. The 2-dimensional

Table 2. Plant species cover in February 2008 in open plains transects with dense *Cytisus scoparius* infestation that had been treated with herbicide in December 2007, Edwards Plain, Barrington Tops National Park.

Genus / species (family (subfamily)) * = naturalised	**Cover in transects (%)**									**Total Cover (%)**
	1	2	3	4	5	6	7	8	9	
**Cytisus scoparius* (Fabaceae (Faboideae) – dead	86	90	84	88	94	98	90	84	95	89.83
**Cytisus scoparius* – live	0	0	0.2	0	23	3	0.2	0.3	2.5	3.22
Poa sieberiana (Poaceae)	94	90	100	96	91	39	40	100	100	83.27
Microlaena stipoides var. *stipoides* (Poaceae)			0.1	0.1	2.8	5.1	1.1	4.1	0.1	1.49
Hakea microcarpa (Proteaceae)						12.9		0.1		1.44
Carex sp. (JRHosking 2585 *et al.*) (Cyperaceae)	0.1		0.2	1.7	0.8	0.8				0.40
Luzula densiflora or *L. flaccida* (Juncaceae)									1	0.11
Dichelachne inaequiglumis (Poaceae)				0.8					0.1	0.10
Anthosachne rectiseta (Poaceae)				0.5						0.06
Viola fuscoviolacea (Violaceae)							0.5			0.06
Tetrarrhena turfosa (Poaceae)					0.4					0.04
Gonocarpus humilis (Haloragaceae)				0.2						0.02
Hydrocotyle peduncularis (Araliaceae)			0.1	0.1						0.02
Rytidosperma penicillatum (Poaceae)	0.1		0.1							0.02
**Acetosella vulgaris* (Polygonaceae)				0.1						0.01
Oreomyrrhis eriopoda (Apiaceae)			0.1							0.01
Wahlenbergia ceracea (Campanulaceae (Campanuloideae))				0.1						0.01
Number of species, including *Cytisus scoparius*	4	2	7	10	5	5	4	4	5	
Average age (years) of older *Cytisus scoparius* plants based on growth ring counts (yr) of three shrubs in areas near transects	16	14	18	13	17	12	13	14	13	
Groundcover for live species	94	90	101	100	118	61	42	105	104	
Groundcover for live species other than *Poa sieberiana* and *Cytisus scoparius*	0.2	0	0.6	3.6	4	18.8	1.6	4.2	1.2	

solution to the NMDS analysis (Figure 5) shows each transect as a plotted point (*Cytisus scoparius* transects = 1A–9A, transects with no *Cytisus scoparius* = 1B–9B). Similarities in species composition between transects is shown by their positions and the distances between those plotted points. Most of the *Cytisus scoparius* transects are clustered near the centre of the diagram, indicating a near uniform community structure whereas the transects with no *Cytisus scoparius* are more dispersed, indicating greater diversity of species.

Data on annual changes in groundcover abundance of species along a 20 m *Cytisus scoparius* infested line transect on Edwards Plain was available for the period 2003–2008 (Table 3, Figure 6). The transect was herbicide treated in December 2007 prior to the 2008 recording but decreases in the cover of native species in earlier years is presumably due to *Cytisus scoparius* competition/shading. This shows a marked decrease in groundcover for species other than *Cytisus scoparius* and *Poa sieberiana* over the 5 year period (e.g. *Oreomyrrhis eriopoda*). In 2008 based on growth rings *Cytisus scoparius* plants ranged in age from 11 to 19 years of age with an average age of 14.5 years (Table 2) suggesting that shading impacts had probably been present for at least a decade. High levels of dead *Cytisus scoparius* groundcover prior to herbicide treatment were due to naturally occurring lower branch death.

Comparison with flora in the study area in the 1930s

Importantly while our study indicated high levels of *Cytisus scoparius* in the study area now, Fraser & Vickery (1939) did not mention *Cytisus scoparius* as being present in this area, or in other areas of native vegetation on the Barrington Tops. This supports the Waterhouse (1988) evidence and indicates that the invasion of *Cytisus scoparius* has been relatively recent.

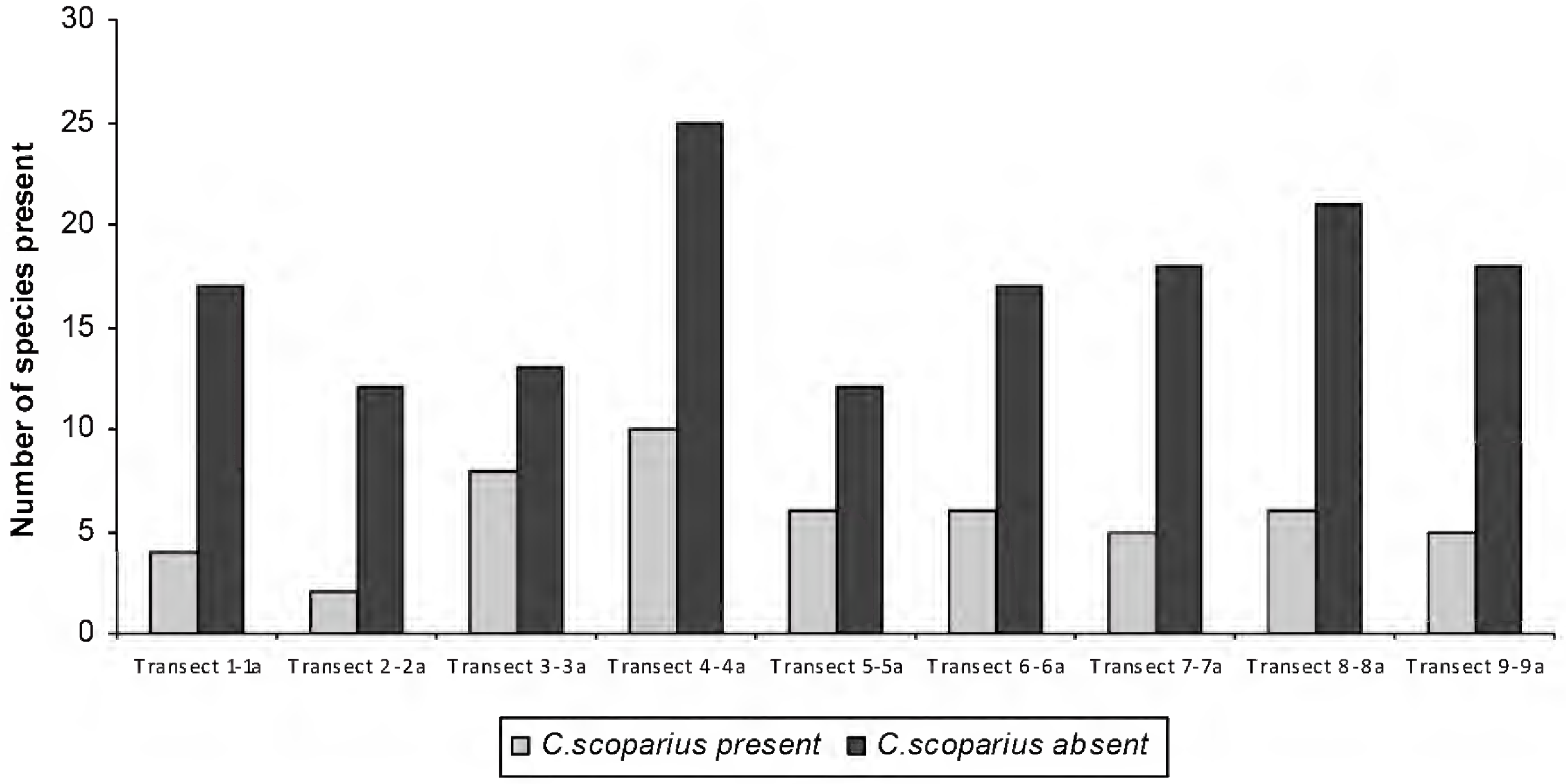

Fig. 3. A comparison of the number of species found in 10 m line transects in areas with and without *Cytisus scoparius* on Edwards Plain.

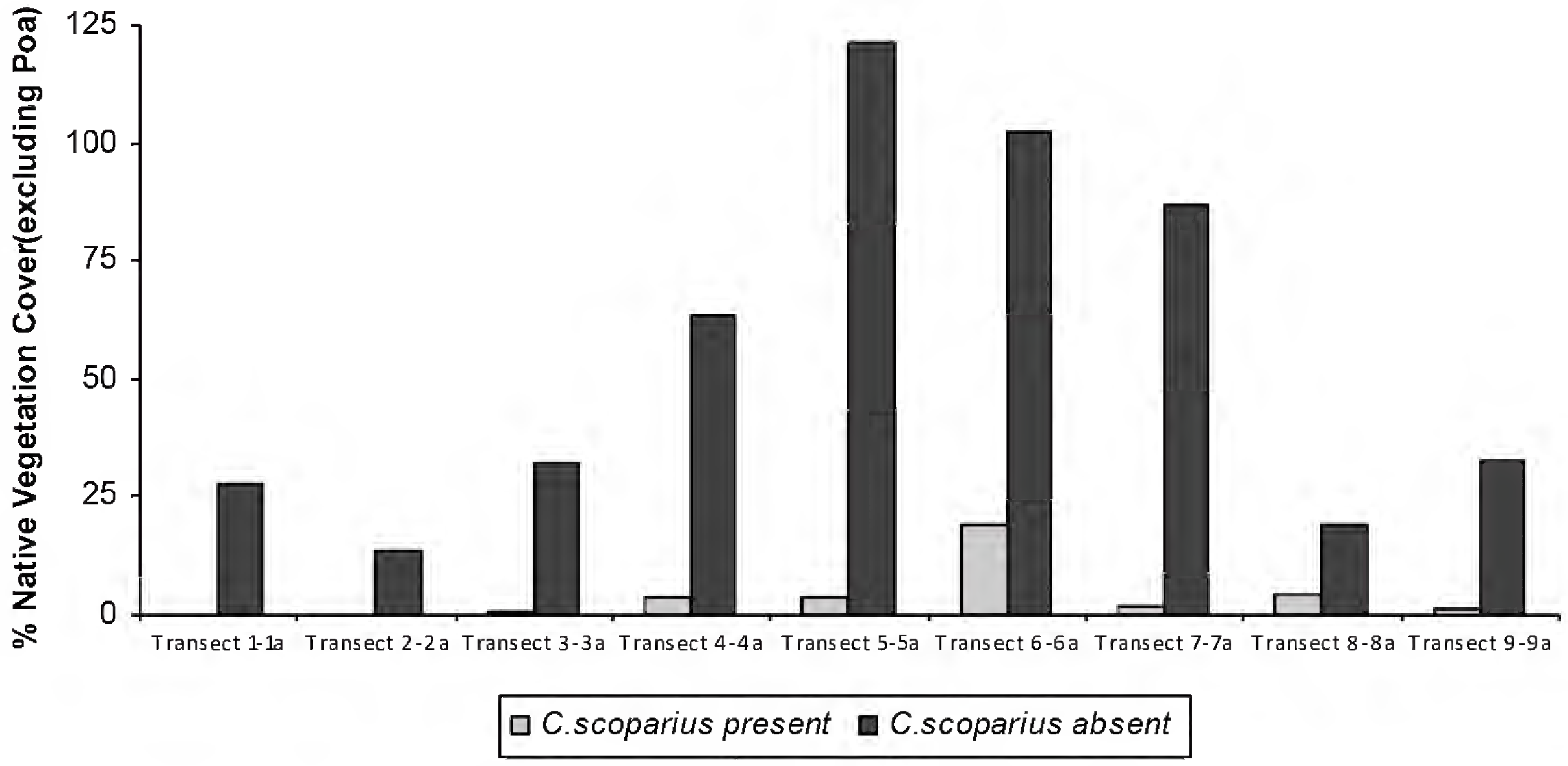

Fig. 4. A comparison of the area occupied by native vegetation in 10 m line transects in areas with and without *Cytisus scoparius* on Edwards Plain. Cover of *Poa sieberiana* is not included in the figure as it is common in areas with and without broom.

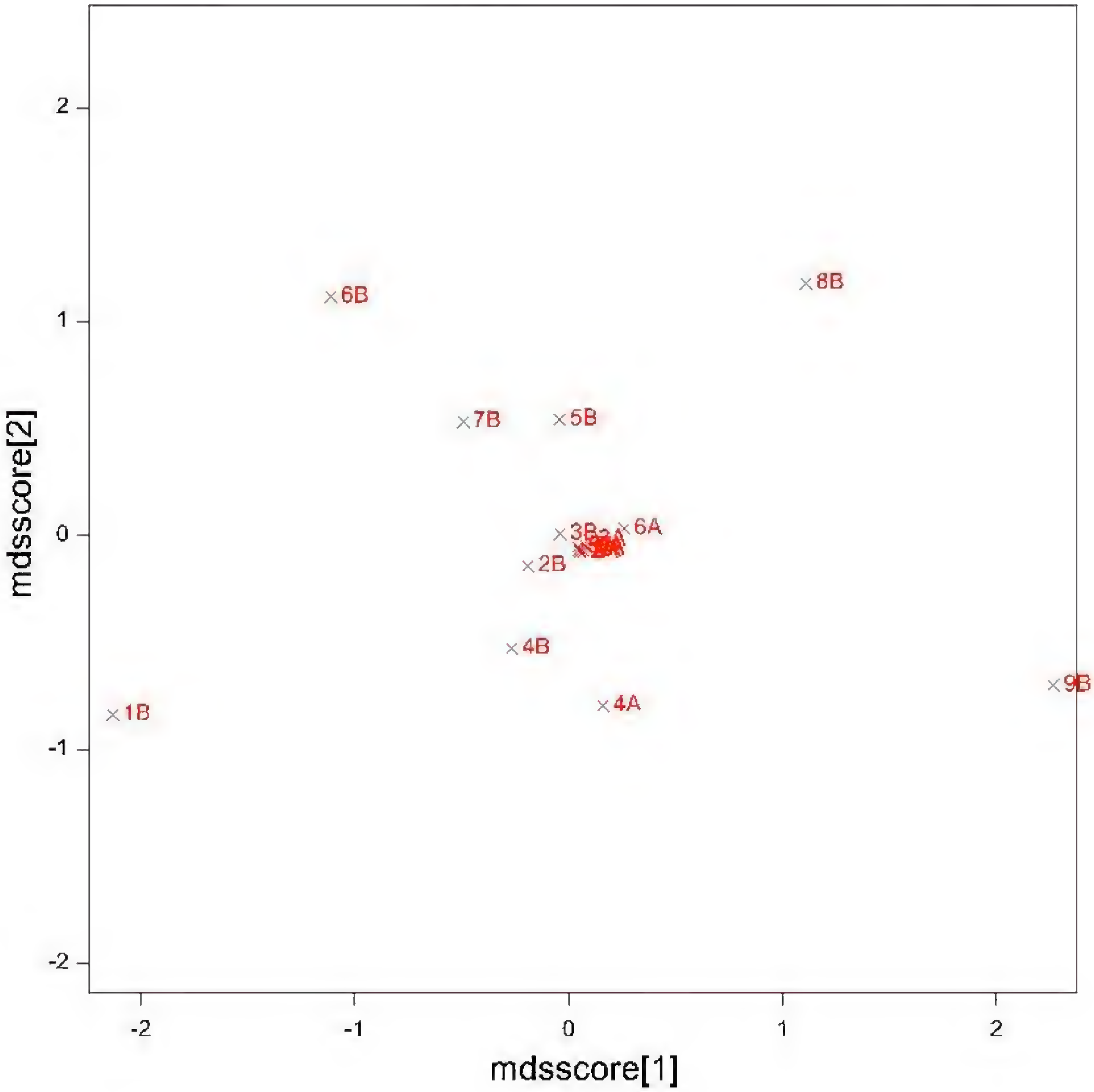

Fig. 5. Non-metric multidimensional scaling 2D solution (stress = 0.0887) showing *Cytisus scoparius* (A) and non-*Cytisus scoparius* (B) transects (N.B. transect data used to create the Euclidean distance matrix excluded *Cytisus scoparius*). Similarities in species composition between transects is shown by their positions and the distances between these plotted points. Most of the *Cytisus scoparius* transects are clustered near the centre of the diagram, indicating a near uniform community structure for these transects.

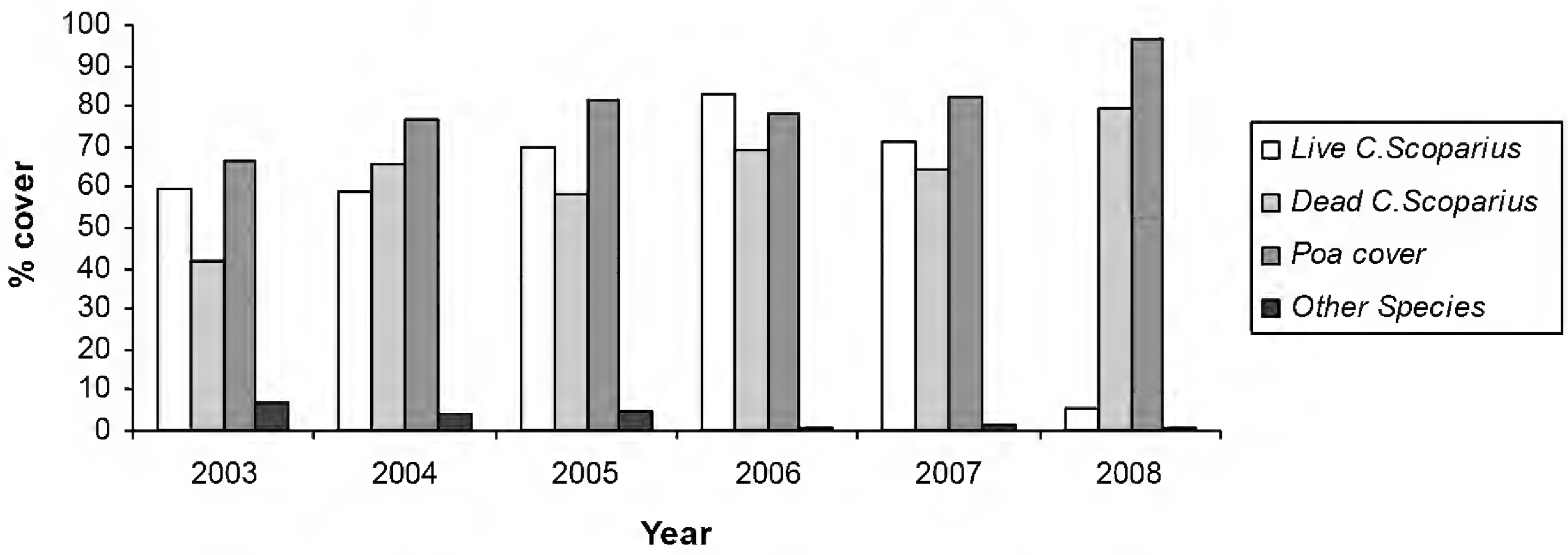

Fig. 6. Plant species present in a 20 metre line transect through *Cytisus scoparius* from 2003 to 2008 on Edwards Plain.

A comparison of the species lists for this study (Tables 1 and 2) with that of Fraser & Vickery (Table 4) shows that most of the species found in the earlier study can still be found in the area, though one very common species in treeless areas now, *Tetrarrhena turfosa,* surprisingly is not mentioned in their publication but was collected by Joyce Vickery in 1934 (at that time labelled *Tetrarrhena juncea*).

Some of the common species listed for this area in Fraser & Vickery (1939) were not encountered in the nine paired transects on Edwards Plain. *Lycopodium fastigiatum* was listed as locally common by Fraser & Vickery and is still present in the area, but was not encountered in the transects. *Acrothamnus hookeri*, *Acacia barringtonensis*, the exotic *Lotus corniculatus*, *Persoonia acuminata* and *Pimelea linifolia* subsp. *linifolia*, were not encountered in our study but are still known from other areas on the Barrington Tops. Recent collections and observations at various times of the year suggest the species referred to as *Acrothamnus hookeri* from frost-hollow areas is likely to be a rhizomatous taxon that does not form flowers. *Acrothamnus hookeri* that forms fruits and flowers is locally common in woodlands and open forest elsewhere on the Barrington Tops.

Fraser & Vickery listed many orchid species as locally common but we could not determine the species present in our transects as they were not in flower, and above ground parts of some species may not have been present. Fraser & Vickery found many more orchids in treeless areas; this is probably a result of the timing of their visits to the Barrington Tops relative to our February study. Based on dates of specimens that they collected they appear to have mainly been collecting in the area in January over a number of years. One orchid species, *Diurus venosa*, listed in Fraser & Vickery (1939) as locally common is now listed as Vulnerable under the *NSW Threatened Species Conservation Act 1995*. This species is still present in the study area but the species is not obvious in February. It is common in many areas on the Barrington Tops.

The voucher specimen for *Viola hederacea* collected by Fraser & Vickery has been redetermined as *Viola fuscoviolacea* (Figure 7). Both *Viola hederacea* and *Viola fuscoviolacea* are present on the Barrington Tops and were probably confused by Fraser & Vickery (as they were by J.R. Hosking initially). They did however point out that the species found in the swamps (*Viola fuscoviolacea* now) has smaller flowers and

Table 3. Plant species cover along a 20 metre line transect through *Cytisus scoparius* **recorded annually from 2003 to 2008.** *Cytisus scoparius* herbicide treated in December 2007, Edwards Plain, Barrington Tops National Park.

Genus and species (family (subfamily)) * = naturalised	**Cover in transects (%) from 2003 to 2008**					
	8.iv.2003	31.ii.2004	23.ii.2005	21.ii.2006	20.ii.2007	25.ii.2008
**Cytisus scoparius* – live (Fabaceae (Faboideae))	59	59	70	84	71	6
**Cytisus scoparius* – dead (Fabaceae (Faboideae))	42	66	58	69	65	80
Poa sieberiana (Poaceae)	65	77	81	78	82	96
Hakea microcarpa (Proteaceae)		2.1	2.5			
Carex sp. (JRHosking 2585 *et al.*) (Cyperaceae)		0.45	0.95	0.5	0.15	0.45
Oreomyrrhis eriopoda (Apiaceae)	2.3	0.05	0.1			
**Cerastium vulgare* (Caryophyllaceae)	1.8		0.05			
Wahlenbergia ceracea (Campanulaceae (Campanuloideae))	0.25	0.6	0.25	0.05	0.25	
Hydrocotyle peduncularis (Araliaceae)	1	0.05				
Microlaena stipoides var. *stipoides* (Poaceae)				0.25	0.5	
Gentianella barringtonensis (Gentianaceae)	0.55					
**Hypochaeris radicata* (Asteraceae)	0.5					
Pratia pedunculаris (Campanulaceae (Lobeloideae))	0.5					
Luzula densiflora and/or *L. flaccida* (Juncaceae)		0.35				
Scleranthus sp. (JRHosking 2489) (Caryophyllaceae)		0.05	0.25			
Gonocarpus humilis (Haloragaceae)		0.1	0.15			
Viola fuscoviolacea (Violaceae)			0.25			
Carex sp. (JRHosking 2873) (Cyperaceae)					0.15	
Dichelachne inaequiglumis (Poaceae)					0.15	
Juncus sp. (Juncaceae)			0.15			
Rytidosperma penicillatum (Poaceae)						0.1
Viola betonicifolia (Violaceae)		0.1				
Epilobium billardierianum subsp. *cinereum* (Onagraceae)			0.05			
Stellaria flaccida (Caryophyllaceae)		0.05				
Groundcover for live species other than *Poa sieberiana* and *Cytisus scoparius*	6.9	3.9	4.7	0.8	1.2	0.55
Number of species (including *Cytisus scoparius*)	9	12	12	5	6	4

Table 4. Species frequencies recorded by Fraser & Vickery (1939) in subalpine grassland at the Barrington Tops, with updated nomenclature. Frequencies classes used were: Rare, Scanty, Frequent, Common, Locally Common and Very Common

Order & family (subfamily), current use	Order & family in Fraser & Vickery (where different)	Fraser &/or Vickery voucher at NSW or SYD (v)	Genus and species, current use, * = naturalised	Genus / species in Fraser & Vickery (where different)	Frequency in Fraser & Vickery
Pteridophytes					
Lindsaeaceae	Polypodiaceae	v	*Lindsaea linearis*	*Lindsaya linearis*	Scanty
Lycopodiaceae		v	*Lycopodium fastigiatum*	*Lycopodium clavatum* var. *fastigiatum*	Locally common
Polypodiaceae			*Microsorum pustulatum* subsp. *pustulatum*	*Pleopeltis diversifolia*	Scanty
Monocotyledons					
Asparagaceae (Lomandroideae)	Liliaceae		*Arthropodium milleflorum*	*Arthropodium paniculatum*	Common
		v	*Lomandra longifolia*		Rare
Cyperaceae			*Isolepis* sp.	*Scirpus setaceus*	Frequent
		v	*Lepidosperma tortuosum*	*Schoenus ericetorum*	Frequent
			Schoenus apogon		Frequent
Juncaceae		v	*Luzula meridionalis*	*Luzula campestris*	Frequent
Orchidaceae		v	*Diuris venosa*		Locally Common
			Microtis rara?	*Microtis parviflora*	Frequent
			Microtis unifolia	*Microtis porrifolia*	Frequent
		v	*Prasophyllum brevilabre*		Locally Common
		v	*Prasophyllum odoratum s.lat.* & *Prasophyllum patens*	*Prasophyllum odoratum*	Locally Common
		v	*Thelymitra ixioides*		Locally Common
Poaceae	Gramineae	v	*Deyeuxia gunnii*	*Deyeuxia breviglumis*	Frequent to Common
		v	*Poa sieberiana s.lat.*	*Poa caespitosa s.lat.*	Very common
Restionaceae		v	*Empodisma minus*	*Hypolaena lateriflora*	Frequent
Dicotyledons					
Araliaceae	Umbelliferae	v	*Hydrocotyle peduncularis*	*Hydrocotyle hirta*	Scanty
Asteraceae	Compositae	v	*Craspedia canens* & *Craspedia variabilis*	*Craspedia Richea*	Common
		v	*Lagenophora montana* & *Lagenophora stipitata*	*Lagenophora Billardieri*	Scanty
		v	*Solenogyne gunnii*	*Lagenophora emphysopus*	Locally Common
		v	*Xerochrysum bracteatum* with yellow involucral bracts	*Helichrysum lucidum*	Locally Common
		v?	*Xerochrysum bracteatum* with white involucral bracts	*Helichrysum elatum*	Common
Campanulaceae (Campanuloideae)	Campanulaceae		*Wahlenbergia ceracea*	*Wahlenbergia gracilis*	Frequent
Campanulaceae (Lobeloideae)	Campanulaceae		*Pratia pedunculata*	*Lobelia pedunculata*	Frequent
Caryophyllaceae		v	*Scleranthus* sp. (same as JRHosking 2489)	*Scleranthus biflorus*	Frequent
Ericaceae (Epacridoideae)	Epacridaceae	v	*Acrothamnus hookeri*	*Leucopogon Hookeri*	Common
		v	*Leucopogon pilifer*	*Leucopogon collinus*	Locally Common
Fabaceae (Faboideae)		v	*Hovea heterophylla*		Scanty
		v	**Lotus corniculatus*		Common
			Pultenaea fasciculata		Locally Common
			Sphaerolobium minus	*Sphaerolobium vimineum*	Scanty
			**Trifolium repens*		Rare
Fabaceae (Mimosoideae)	Leguminosae	v	*Acacia barringtonensis*	*Acacia Clunies-Rossiae*	Locally Common
Goodeniaceae		v	*Scaevola hookeri*	*Scaevola Hookeri*	Locally Common

Order & family (subfamily), current use	**Order & family in Fraser & Vickery (where different)**	**Fraser &/or Vickery voucher at NSW or SYD (v)**	**Genus and species, current use, * = naturalised**	**Genus / species in Fraser & Vickery (where different)**	**Frequency in Fraser & Vickery**
Lamiaceae	Labiatae	v	*Ajuga australis s.lat.*	*Ajuga australis*	Frequent
Loganiaceae		v	*Mitrasacme serpyllifolia*		Frequent
Oenotheraceae		v	*Epilobium billardierianum* subsp. *cinereum*	*Epilobium glabellum*	Scanty
Orobanchaceae	Scrophulariaceae	v	*Euphrasia ciliolata*	*Euphrasia Brownii*	Scanty
Plantaginaceae		v	*Plantago cladorophylla*	*Plantago varia*	Scanty
Polygalaceae		v	*Comesperma retusum*	*Comesperma sylvestre*	Scanty
Proteaceae		v	*Hakea microcarpa*		Locally Common
		v	*Persoonia acuminata*	*Persoonia oxycoccoides*	Locally Common
Ranunculaceae		v	*Ranunculus lappaceus*		Very Common
Santalaceae		v	*Exocarpos nanus*	*Exocarpus nana*	Scanty
Stylidiaceae	Candolleaceae	v	*Stylidium graminifolium*	*Candollea serrulata*	Common
Thymelaeaceae		v	*Pimelea linifolia* subsp. *linifolia*	*Pimelea linifolia*	Locally Common
Violaceae		v	*Viola betonicifolia*		Scanty
		v	*Viola fuscoviolacea*	*Viola hederacea*	Scanty

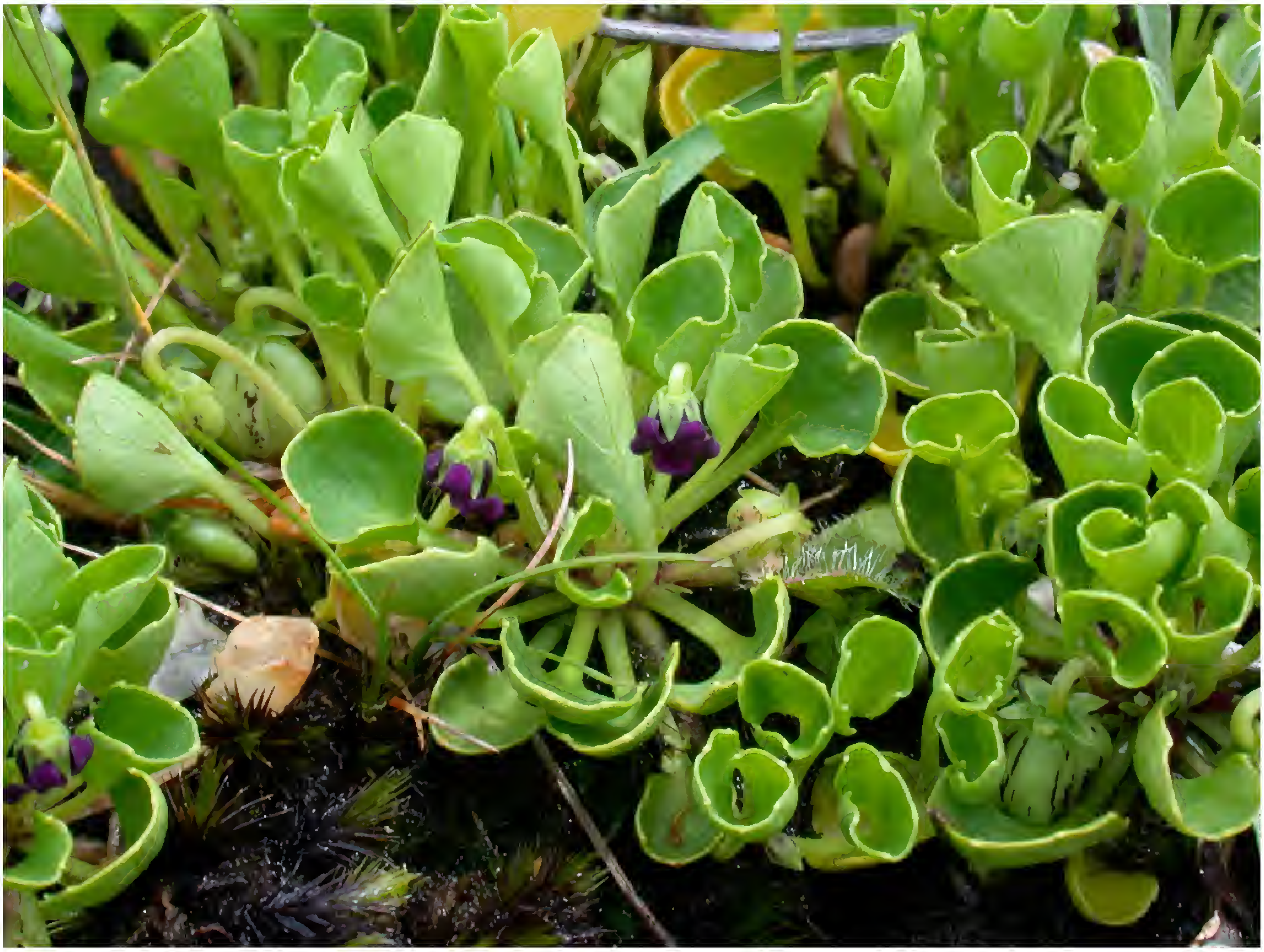

Fig. 7. *Viola fuscoviolacea*, a species found in treeless frost hollow vegetation, that was at one time included in *Viola hederacea s.lat.*

leaves than the form found in other areas (*Viola hederacea* now). *Viola fuscoviolacea* is not only common in swamps but is also locally common in frost-hollow areas on the Barrington Tops. There is uncertainty regarding the identity of species referred to as *Xerochrysum lucidum* by Fraser & Vickery; this specimen could not be located at the National Herbarium of NSW.

Fraser & Vickery did not note a few of the species common now, particularly *Carex* sp. (collection J.R.Hosking 2585 *et al.*), an unnamed species that has been mistaken for *Carex appressa* in the past. *Carex appressa,* a different taxon, is present alongside watercourses in the area. Nor did they mention many Poaceae species; these are much more obvious when inflorescences are present and would not have been obvious if collections were made in January or earlier in the Australian summer.

One species found in this study, *Euphrasia ciliolata*, is listed as vulnerable on the NSW *Threatened Species Conservation Act 1995*; it is still reasonably common in this area and in other areas on the Barrington Tops. Numbers appear to vary considerably from year to year.

Discussion

Our results indicate that *Cytisus scoparius* is having a major competitive impact on native vegetation in naturally treeless frost-hollow vegetation communities on the Barrington Tops. These vegetation communities are of limited extent and significant in ecological and biogeographical terms. Disjunct patches of naturally treeless frost-hollow vegetation communities are found at higher altitudes along the Great Dividing Range in southern New South Wales and Victoria. For example a study on Nungar Plain vegetation, a treeless sub-alpine frost-hollow in Kosciuszko National Park (McDougall & Walsh 2002) demonstrates the similarity in species. This similarity of high elevation vegetation was earlier pointed out by Fraser & Vickery (1939), but a number of species thought to be the same in the past are now considered to be different, indicating the importance of conserving as many of the disjunct patches as possible. For example *Gentianella barringtonensis* was previously part of *Gentiana diemesis* (recorded in Fraser & Vickery (1939) from a nearby area but not from subalpine grassland), a species complex that has subsequently been separated into a number of *Gentianella* species, and the *Scleranthus* species that was included in *Scleranthus biflorus,* is evidently a different unnamed taxon

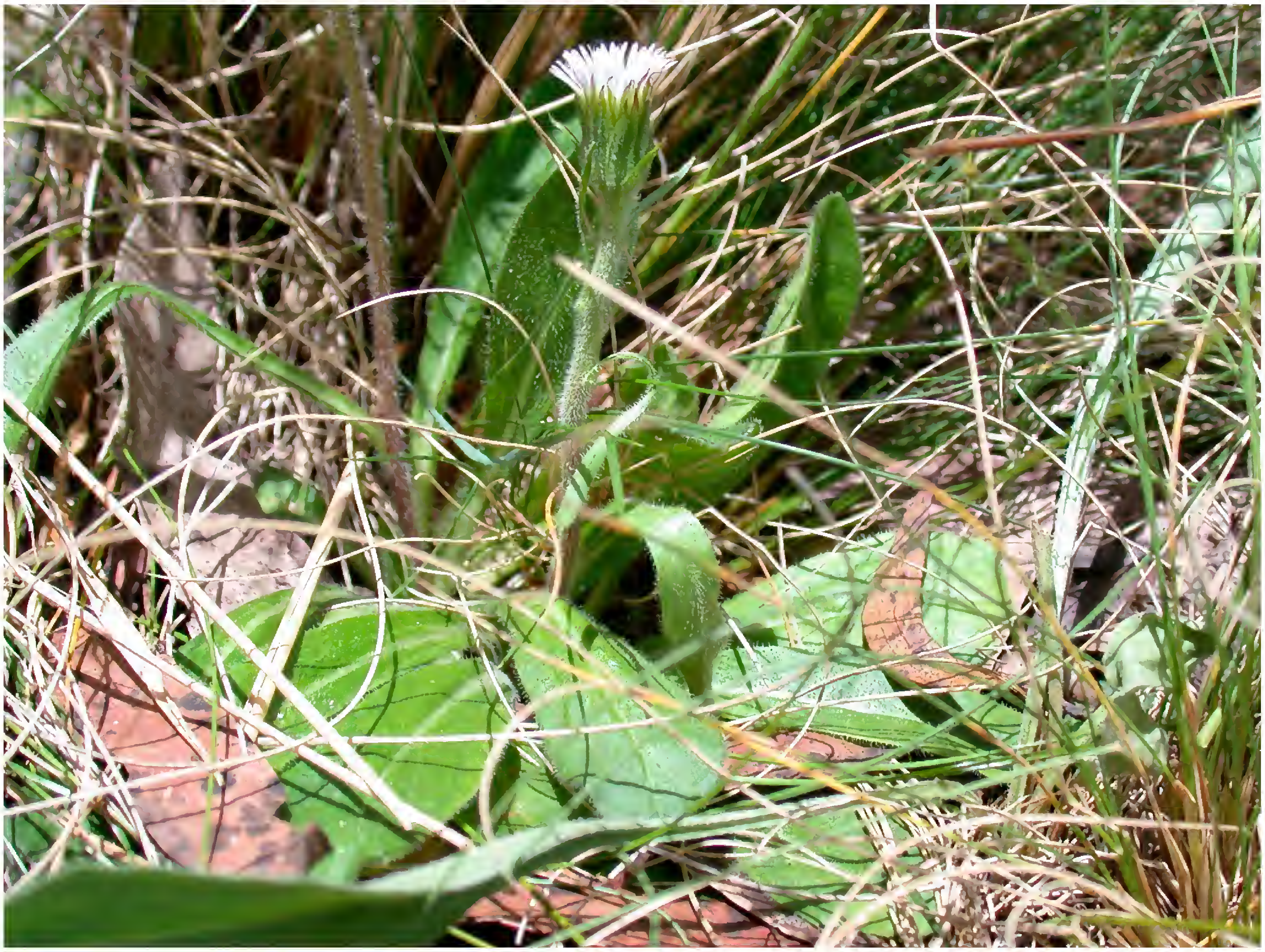

Fig. 8. *Erigeron bellidioides*, a species only recorded from treeless areas.

(J. West pers. comm. 1995). Other species are likely to be different on further study as the Barrington Tops does not appear to have had high levels of taxonomic study in the past.

A number of the species recorded in this study have only been observed and collected in treeless areas though some of these are also found in swamps and alongside watercourses in treeless areas. All of these areas are impacted by *Cytisus scoparius*. Species only recorded from treeless areas include *Tetrarrhena turfosa*, *Empodisma minus*, *Erigeron bellidioides* (Figure 8), *Leucopogon pilifer*, *Velleia montana* *Mitrasacme serpyllifolia* and *Xerochrysum bracteatum* (form with leaves mainly in a basal rosette at flowering and with yellow involucral bracts – one of three or four forms of *Xerochrysum bracteatum* found on the Barrington Tops),

Impact of Cytisus scoparius

Only *Poa sieberiana* and *Hakea microcarpa* appear to survive at reasonable levels in dense *Cytisus scoparius* infestations. With the exception of *Hakea microcarpa* which never forms dense stands that would exclude light from lower vegetation these naturally treeless frost-hollow areas have little in the way of tall shrubs. The impact of *Cytisus scoparius*, although it loses its leaves in cooler months, is not surprising if you consider that most other plants in this area are not subject to dense shade over warmer months. Many of the plant species in this treeless vegetation community are not found in surrounding woodland vegetation communities despite these areas having an open forest canopy with high light penetration to the ground layer. *Cytisus scoparius* also adversely affects open forest areas without a native shrub and vine understorey (Waterhouse 1988, J.R. Hosking and M. Schroder unpubl.), but in areas where there is a native shrub and vine understorey *Cytisus scoparius* appears to have little impact on the native vegetation with *Cytisus scoparius* plants growing and dying without ever becoming a dominant species (J.R. Hosking and M. Schroder unpubl.).

Wearne & Morgan (2004) reported a loss of native species or a reduction in their abundance associated with *Cytisus scoparius* invasion in a subalpine area in Victoria, in *Eucalyptus pauciflora* woodland with an open shrubby understorey. Such areas occur on the Barrington Tops but were not in our study area. Wearne & Morgan (2006) also reported on seed rain in *Cytisus scoparius* stands compared with areas outside *Cytisus scoparius* stands. The seed rain showed significant decreases in species richness and seed density in areas that had been invaded for a long time. Our study was in a different type of vegetation community but did show a similar decrease in numbers and cover of native species. The impact of *Cytisus scoparius* on seed banks or seed rain of native species has not been determined in our study but the lack of native species would indicate that there is likely to be little in the way of native species seed rain in the area.

In India, in grasslands of the Nilgiri Hills, *Cytisus scoparius* at intermediate densities decreased abundance of light demanding species, and increased shade tolerant species from neighbouring areas (Srinivasan *et al.* 2007). Shade tolerant species can establish under *Cytisus scoparius* in woodlands elsewhere on the Barrington Tops (unpubl. data J.R. Hosking and M. Schroder) though these shade tolerant species do not survive in the colder conditions that occur in open grasslands compared with treed areas, or do not appear to have reached this area.

There are other studies where the impact of an invasive shrub species shows similar impacts on native vegetation. The impact of the South African shrub *Chrysanthemoides monilifera* subsp. *rotundata* bitou bush on native vegetation on the New South Wales coast was found to vary depending on the vegetation community where it occurred, with this species decreasing cover abundance of native grasses and herbs in fore dune sites that normally have little in the way of trees or shrubs (Mason & French 2008). In fynbos vegetation in South Africa the Australian shrub *Acacia saligna* decreased species richness, cover and frequency much the same as *Cytisus scoparius* did in this study (Holmes & Cowling 1997). In California Hobbs & Mooney (1986) showed that invasion of grassland by the native shrub species, *Baccharis pilularis* subsp. *consanguinea*, significantly changed the abundance of herbaceous grassland species through reduction of light reaching the ground, and increased herbivory. Although not measured in our study, light was decreased in *Cytisus scoparius* stands, particularly when *Cytisus scoparius* was in leaf. Whether herbivory changes in, or at the edges of *Cytisus scoparius* stands on treeless plains on the Barrington Tops compared with more exposed grassland areas is not known. Even grasses taller than herbs in invaded communities can cause significant losses of herbaceous species e.g. for *Imperata cylindrica* invasion of longleaf pine (*Pinus palustris*) communities in southeastern Mississippi (Brewer 2008).

Possible changes to management in this area

Our results indicate that *Cytisus scoparius* has reduced the number and groundcover of species in the area compared with what is found in areas without *Cytisus scoparius* (Table 1), and control of *Cytisus scoparius* in this area is justified to prevent its further spread. However, we recommend that the control technique used must consider the potential impact to surrounding native vegetation communities. Where only individual *Cytisus scoparius* small plants are present these should be removed manually as this will have less impact on native vegetation than foliar applied herbicide. Where infestations are more dense (up to 40% cover) the cut and paint method using glyphosphate carefully applied to stems close to the ground is recommended. For dense stands where non target damage to surrounding vegetation communities can be avoided the first treatment is likely to be more cost efficient using foliar application of a recommended broad leaf herbicide. However follow-up seedling control should be limited to physical removal to encourage natural regeneration and limit off target damage.

The herbicide being used to control *Cytisus scoparius* is likely to impact on other species as was the case where (a different) herbicide was used to control bitou bush, *Chrysanthemoides monilifera* subsp. *rotundata*, in coastal New South Wales

(Matarczyk *et al.* 2002, Mason & French 2007, Mason *et al.* 2007). However, as *Cytisus scoparius* appears to be able to exclude most other species from densely infested areas attempts need to be made to limit its spread.

Our study found that exotic species, other than *Cytisus scoparius*, contributed little to ground cover in naturally treeless frost-hollow areas. In a similar area of frost-hollow grasslands in Kosciuszko National Park in southern New South Wales where *Cytisus scoparius* was not present, Godfree *et al.* (2004) found that exotic species contributed little to the cover of species in the area. Interestingly, the most common exotic species found by Godfree *et al.* (2004) were also recorded in our study, these being *Hypochaeris radicata*, *Acetosella vulgaris*, *Trifolium repens* and *Cerastium vulgare*. Removal of *Cytisus scoparius* from Edwards Plain and similar frost-hollow areas should not lead to an increase in any of the exotic species recorded from elsewhere in frost-hollow areas.

There is no guarantee that areas from which *Cytisus scoparius* has been removed will recover diversity to levels of areas that have never had *Cytisus scoparius*. A single transect (near Transect 2 of Table 1– results not shown) from which *Cytisus scoparius* had been removed about two years previously was still dominated by *Poa sieberiana* (89% ground cover) with a small amount of cover of a few other species (0.5% *Oreomyrrhis eriopoda*, 0.1% *Arthropodium milleflorum* and 0.4% *Cytisus scoparius*). One transect is insufficient to draw conclusions from but it does suggest that recovery of species diversity and cover may not be rapid. *Acacia saligna* invasion of fynbos vegetation in South Africa significantly reduced seed bank diversity and richness of native species (Holmes 2002). This may also be the case in frost hollow vegetation at the Barrington Tops.

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